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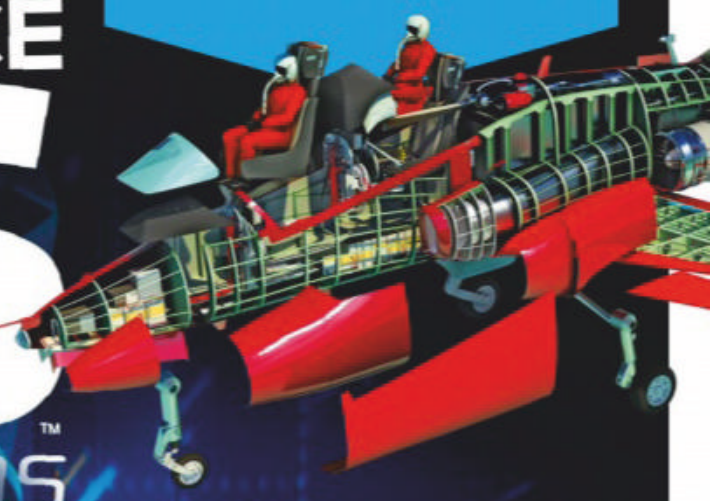

FROZEN IN TIME

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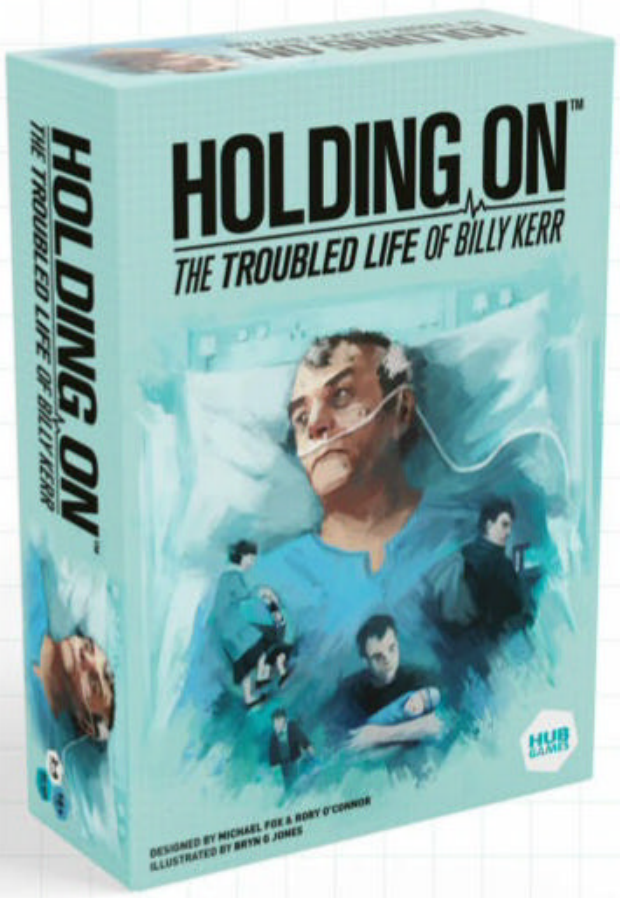
FUTURE
ISSUE 124

HOLDING ON™
THE TROUBLED LIFE OF BILLY KERR

2-4 PLAYERS

14+ AGE

45-60 MINUTES



'All my life I've kept my mouth shut - out of loyalty, out of fear... out of shame. And look where it's got me, lying here with my rear-end hanging out of a blue gown, all you lot fussing around me. Sure, that's no way to live. No way to die.'

Holding On: The Troubled Life of Billy Kerr is a co-operative game where players uncover the story of a dying man during his final days.

A truly emotionally impactful game, Holding On is a deep but accessible game that tells the extraordinary story of an ordinary life.

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HUB GAMES

ISSUE 124

WELCOME

The magazine that feeds minds!

"You can see the patient's internal structures mapped onto their body"

Robot surgeons, page 22

Meet the team...

James
Production Editor
Discover the ingenious methods astronomers use to see into deep space and spot objects billions of light years away, on page 36.

Scott
Staff Writer
From frozen wastelands to sun-drenched sands: discover more about Earth's deserts and how they formed on page 50.

Baljeet
Research Editor
Light doesn't always travel in a straight line, and when it bends it can create amazing rainbows and mirages. Find out how on page 32.

Duncan
Senior Art Editor
The Tiger tank was a terrifying sight on the battlefields of WWII. Turn to page 80 to find out what made this machine so fearsome.

Wherever there's a marriage of amazing technologies, the result is often greater than the sum of its parts. You might only ever encounter virtual and augmented reality features in your smartphone or on a games console, but it's set to be the standard for surgeries of the future. Step into a surgeon's shoes on page 22 and find out how robots, VR and AR are revolutionising hospitals. On page 70, we delve into a pet subject of my own: how prehistoric animals, long-extinct, have been so immaculately preserved in Siberian ice, peat bogs and sticky tar pits around the world. Ever wondered what NASA's Mission Control does exactly? Turn to page 40 to find out. This issue you can also find out why birds sing, how deserts form, what happens to batteries when we recycle them, and much more. I hope you enjoy the issue!

Ben Biggs Editor

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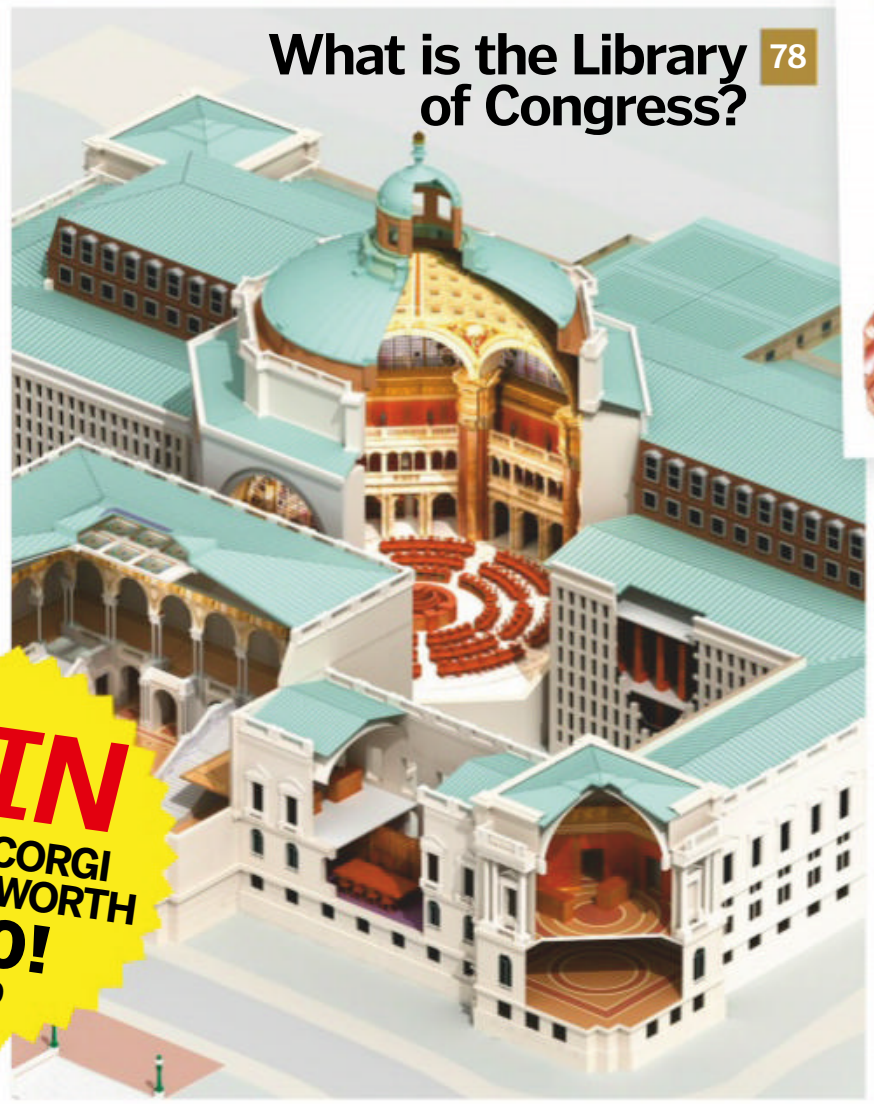

MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.

Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact, and Henry VIII to honey badgers.

Jonathan O'Callaghan
With a background in astrophysics and a love of the mysteries of the cosmos, Jonathan enjoys delving into the wonders of space.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

Tim Williamson
History Of War
Editor-in-Chief Tim has a passion for all things military but studies and writes about a range of historical eras.

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Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

Lee Cavendish
As **All About Space's** resident staffer, Lee is an expert on space topics but enjoys branching out into technology, too.

Jack Parsons
A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but loves to write about projects with much grander ambitions.

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal and conservation projects. She specialises in environment topics.

Jupiter Marble

On 12 February this year, NASA's Juno spacecraft made a close pass of the largest planet in the Solar System. The craft's JunoCam, a mounted visible-light camera that takes photos in strips as the spacecraft spins, took a series of snaps over the course of an hour, between 26,900 and 95,400 kilometres above the tops of Jupiter's clouds. This image of the Great Red Spot and Jupiter's southern hemisphere, dubbed 'Jupiter Marble', was put together using three of JunoCam's images by citizen scientist Kevin M. Gill.

Glowing reactor core

The electric blue light in this photo is not a colour filter added as an after-effect. It shows nuclear fuel plates sent from Idaho National Laboratory's Advanced Test Reactor to Argonne National Laboratory's ATLAS particle accelerator, to learn about their characteristics. They glow fiercely with radioactive energy as they're powered up, which is known as Cherenkov radiation. The core is submerged in water for cooling.

Tiny living pest control

This is a rust mite *(Aceria anthocoptes)* on a plant sample, magnified 1,400 times under an electron microscope. This little living bug is around 60 micrometres long, too small even for the sharpest human eyes to detect. Rust mites were only discovered just over 100 years ago but have since been observed feeding on the invasive plant species Canada Thistle *(Cirsium arvense)*, and have been recognised as a natural pest control method. This plant is native to Europe but is considered a weed when it spreads on other continents.

GLOBAL EYE

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With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.

SPACE

Is Earth a 'galactic zoo'?

Words by **Mindy Weisberger**

Why hasn't Earth received any messages from extraterrestrials yet? One possibility is because we're unwitting inhabitants in a so-called 'galactic zoo'. This was one of the scenarios a group of international researchers explored at a meeting organised by the non-profit organisation Messaging Extraterrestrial Intelligence (METI) last month.

The gathering, which took place at the Cité des Sciences et de l'Industrie museum in Paris, brought together around 60 scientists who've researched the possibility of communication with hypothetical intelligent extraterrestrials. They debated 'The Great Silence' – why aliens haven't contacted us – exploring one possibility known as the 'zoo hypothesis'. First proposed in the 1970s, it describes Earth as a planet that is already under observation by 'galactic zookeepers' who are deliberately concealing themselves from human detection and have agreed to treat Earth as a 'wilderness' area.

If there are intelligent extraterrestrials out there, where are they, and why haven't we found them yet? This conundrum, posed in 1950 by Italian physicist Enrico Fermi, is known as Fermi's paradox, and still stymies experts today.

METI president Douglas Vakoch discussed the idea that aliens are aware of Earth and are observing the planet like a zoo. If this is the case, humans should increase efforts to create messages capable of reaching our 'keepers' to demonstrate our intelligence, Vakoch suggested.

But what if we're not part of a vast alien zoo? What if humanity has been evaluated by alien civilisations and 'quarantined' from our galactic neighbours? It's possible that extraterrestrials are actively isolating us from contact for our own good, because interacting with aliens would be 'culturally disruptive' for Earth, said the meeting co-chair Jean-Pierre Rospars, honorary research director at the Institut National de la Recherche Agronomique (INRA).

Maybe if we want to hear from aliens we just need to be patient. The Earth has existed for over 4.5 billion years, but extraterrestrial research has been going on for less than 50 years, *Paris Match* reported head of the planetarium of the Cité des Sciences et de l'Industrie, Cyril Birnbaum, saying.

Due to melting glaciers, Everest is exposing the bodies of those who died seeking the summit

© Getty

PLANET EARTH

Melting ice on Everest reveals dozens of bodies

Words by **Yasemin Saplakoglu**

Melting glaciers are revealing dozens of dead bodies on the world's highest mountain. The treacherous journey to the summit of Mount Everest is riddled with obstacles such as falling ice, ragged terrain, biting temperatures, dizzying heights and altitude sickness.

While nearly 5,000 people have successfully climbed the mountain, another 300 are thought to have died along the way. Some of these bodies ended up covered in ice and remained hidden for many years. But now climate change is accelerating the ice melt, exposing limbs and bodies.

Last year, a group of researchers found that the ice on Everest was warmer than average, and a study conducted four years ago found that ponds on the mountain were expanding with melting ice water. But it's not only melting glaciers that are exposing these bodies, it's also the movement of the Khumbu Glacier in Nepal.

Removing bodies from the mountain is a delicate, dangerous and costly task riddled with legal constraints – Nepal's law requires government agencies to be involved. What's more, "most climbers like to be left on the mountains if they died" there, mountaineer Alan Arnette told the BBC.

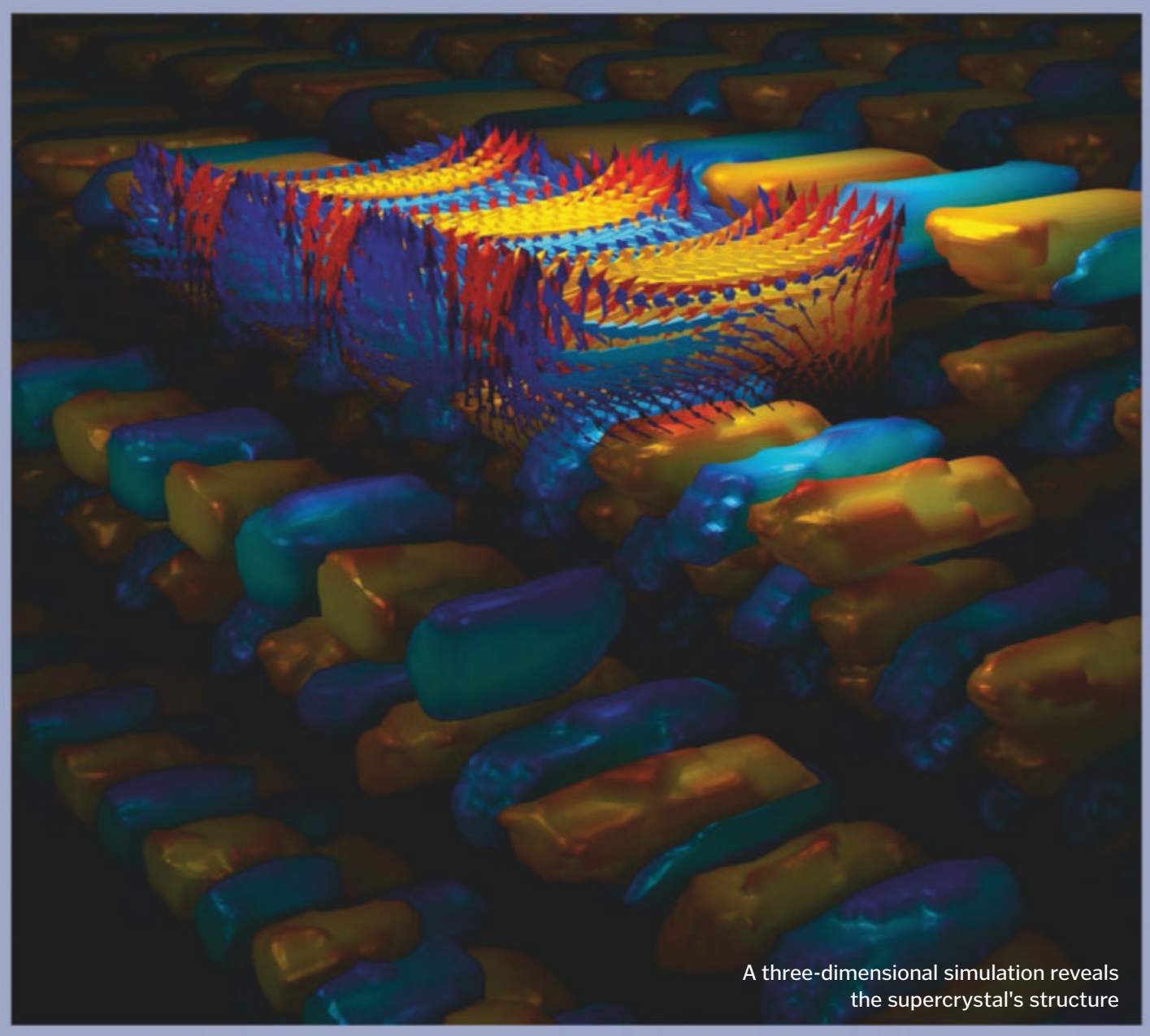
TECH

Scientists create world's first 'supercrystals'

Words by **Rafi Letzter**

A team of physicists have used lasers to create 'supercrystals', even as the structures fought to not exist at all. In the new study, the physicists layered two materials, lead titanate and strontium titanate, on top of each other in such a way that each material frustrated the other's attempts to organise itself into a small-scale crystal. The result was lots of disordered, irregular crystal and non-crystal states scattered randomly throughout the layers.

However, after a superfast zap of blue laser light, the layers reorganised themselves. The laser blast introduced more energy into the system that knocked the crystal into the only sort of organisation that's possible with small-scale crystal units that have been frustrated. A vast, repeating 3D structure soon appeared throughout the material – a structure much larger than those that turn up in other crystals.

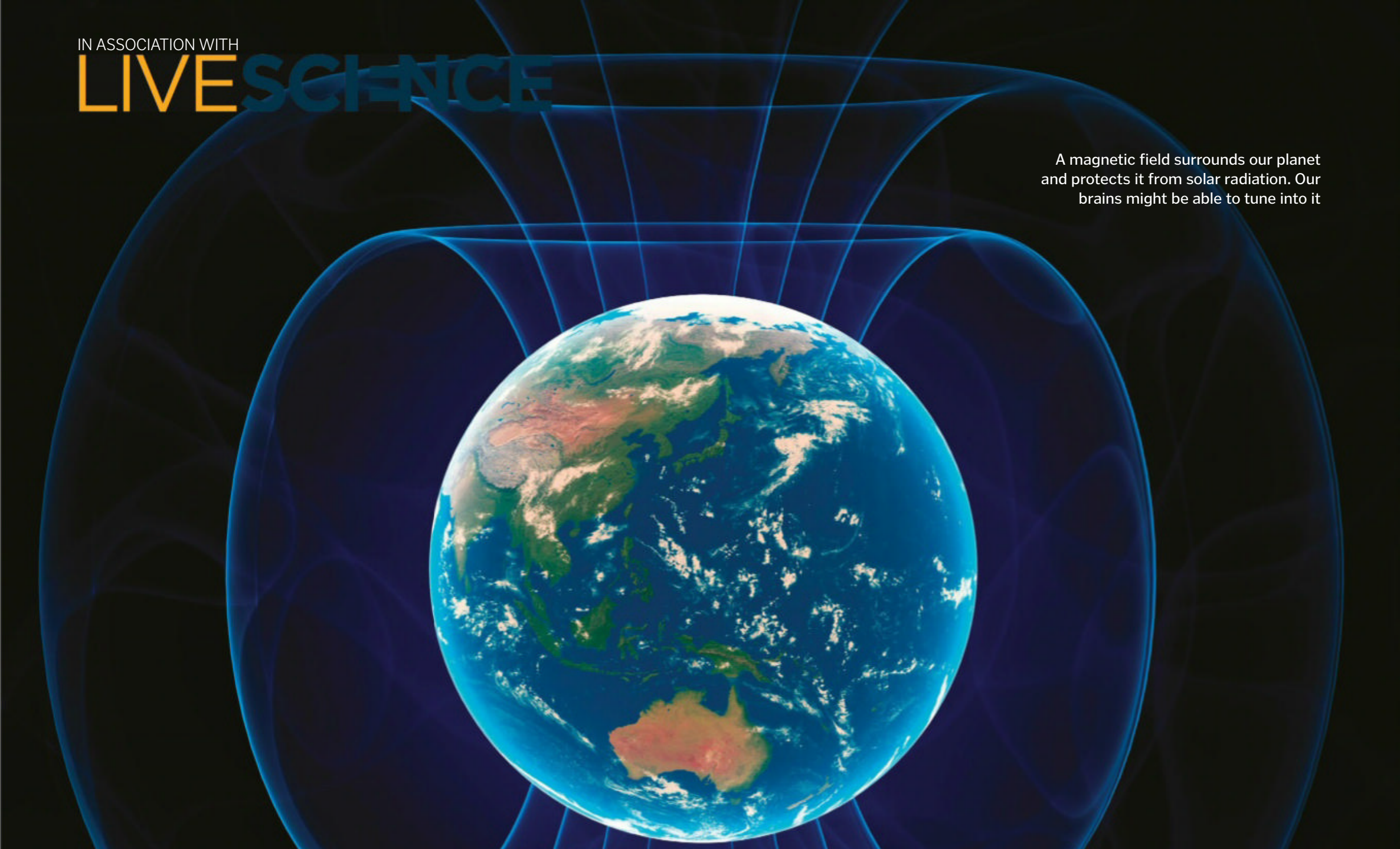


A three-dimensional simulation reveals the supercrystal's structure

© L-Q Chen Group / Penn State

Scientists were able to observe this structure using a second, lower-intensity flash of light. It was the sort of structure that might fleetingly exist as a material shifts from one state to the next, but not one you'd expect to persist long term. However, the researchers showed that this supercrystal survived in room-temperature conditions.

IN ASSOCIATION WITH LIVESCIENCE



A magnetic field surrounds our planet and protects it from solar radiation. Our brains might be able to tune into it

HEALTH

Humans can sense Earth's magnetic field

Words by **Yasemin Saplakoglu**

For some creatures, the magnetic field that hugs our planet serves as a compass for navigation or orientation. Migratory birds, turtles and certain types of bacteria are counted among the species with this built-in navigation system.

But what about humans? According to a recent study, humans can also sense Earth's magnetic field, called magnetoreception. To study whether humans can sense the magnetic field, 34 adults were asked to sit in a dark test chamber adorned with large, square coils. Electric currents travelled through these, changing the magnetic field in the chamber. The intensity of this magnetic field is about the same as the one that surrounds our planet, according to lead study author Connie Wang, a doctoral student at the California Institute of Technology. For comparison, it's about 100,000 times weaker than the ones created by MRI machines, Connie Wang noted.

The participants were told to relax and close their eyes while the researchers manipulated the magnetic field around them. During the experiment, electroencephalogram (EEG) machines measured a type of brainwave called an alpha wave. Alpha waves are known to decrease in amplitude when the brain picks up a signal, whether it is sight, sound or something magnetic.

Of the 34 participants, brain scans from four individuals showed strong reactions to one change in the magnetic field: a shift from northeast to northwest. This would be the same as a person outside the chamber shifting their head quickly from the left to the right, except the head moves through the static magnetic field rather than the field moving around it. In the four individuals, alpha brain waves decreased in amplitude by as much as 60 per cent. However, they responded only when the field shifted from northeast to northwest, not in the other direction. "We weren't really expecting an asymmetrical response," Wang told **Live Science**.

Though it's unclear why this happened, researchers think it could be something unique to individuals, just like how some people are right-handed and some left-handed. Several participants also had a strong response to another set of experiments that shifted the incline of the field, similar to if you travelled between the northern and southern hemispheres. To check the results, the study responders were re-tested weeks later, and the results held true.

HEALTH

Do rusty nails really give you tetanus?

Words by **Yasemin Saplakoglu**

The idea that rusty nails cause tetanus has taken on a life of its own

© Getty

When you think of tetanus, does a rusty nail come to mind? Well, that image might be a little rusty, as tetanus has nothing to do with rust itself. Tetanus is a serious infection caused by *Clostridium tetani* bacteria and can be found throughout our environment, dwelling in places such as soil, dust and faeces.

So why do so many people associate rusty nails with the infection? "Somehow, someone conjured up this image of stepping on a rusty nail [to describe how a person gets tetanus]" Dr. William Schaffner, an infectious diseases specialist at Vanderbilt University told **Live Science**. The image was likely an attempt to convey the idea that the rusty nail was in a dirty environment where these bacteria can be found, he said, but it somehow took "on a life of its own". But "the environment doesn't have to be visibly dirty" for someone to get tetanus, he said. For example, there have been cases where people contracted the infection after slicing their hand with a kitchen knife. In the environment, C. tetani lie dormant in spore form and can survive extreme conditions for long periods of time, as long as oxygen is present, Schaffner said.

When the spores make their way deep into a person's body, their oxygen supply is cut off. It's this lack of oxygen that shakes the bacteria to life. Awakened in the body, the bacteria multiply and produce a toxin that's carried through a person's body in the blood. This toxin, not the bacteria, is what causes tetanus.

A new study shows that ancient microbial life gathered energy from eating their dead neighbours

© Getty

STRANGE NEWS

Dead Sea's dead-eating microbes

Words by **Brandon Specktor**

On its salty surface, the Dead Sea is famous for making tourists float like beach balls. Deep below the surface, however, life is less fun. There, choked by some of the saltiest water on Earth, single-celled microorganisms called archaea struggle to carry on life without oxygen, light or fresh forms of sustenance.

According to a new study, the survival of microbial life beneath the Dead Sea may have once depended on eating the dead. In the study, researchers from Switzerland and France analysed long sediment cores drilled out of the centre of the Dead Sea, and found evidence that ancient microbial life accumulated the energy it needed to survive by gobbling up bits of dead neighbours that couldn't hack the harsh conditions.

According to the researchers, these results open a window into Earth's mysterious deep biosphere, the subterranean world between Earth's surface and its core, where potentially millions of undiscovered microbial species thrive in improbably extreme conditions.

HISTORY

Why do ancient Egyptian statues have broken noses?

Words by **Laura Geggel**

The ancient Egyptians were artistic champions, carving countless statues that showcased the society's pharaohs, religious figures and wealthy citizens. But although these statues depicted different people or beings, many of them share a commonality: broken noses. This broken nose epidemic is so pervasive it makes you wonder whether it was all the result of accidents, or if something more sinister was happening.

It turns out the answer is, in most cases, the latter. These statues have broken noses because many ancient Egyptians believed that statues had a life force. And if an opposing power came across a statue it wanted to disable, the best way to do that was to break off the statue's nose, according to Adela Oppenheim, a curator in the Department of Egyptian Art at The Metropolitan Museum of Art in New York City. It was common to perform ceremonies on statues, including the 'opening of the mouth ritual', in which the statue was anointed with oils and had different objects held up to it, which were believed to enliven it. "This ritual gave the statue a kind of life and power," Oppenheim said.

The belief that statues had a life force was so widespread that it spurred antagonists to extinguish that force when the need arose. For example, people taking apart, repurposing, robbing or desecrating temples, tombs and other sacred sites would have likely believed that statues had life forces that could in some way harm intruders. People would even believe this about hieroglyphs or other images of animals or people. "You basically have to kill it," and one way to do that was to cut off the nose so that it couldn't breathe, Oppenheim explained.

However, sometimes adversaries didn't stop at just the nose. Some also smashed or damaged the face, arms and legs to deactivate the life force. There are likely some instances in which statues naturally tipped over, and a protruding nose broke as a result. Erosion from the elements, such as wind and rain, also likely wore down some statues' noses. But you can usually tell if a nose was destroyed intentionally by looking at cut marks on the statue, Oppenheim divulged.

The face of the Egyptian pharaoh Senwosret III, circa 1878–1840 BCE

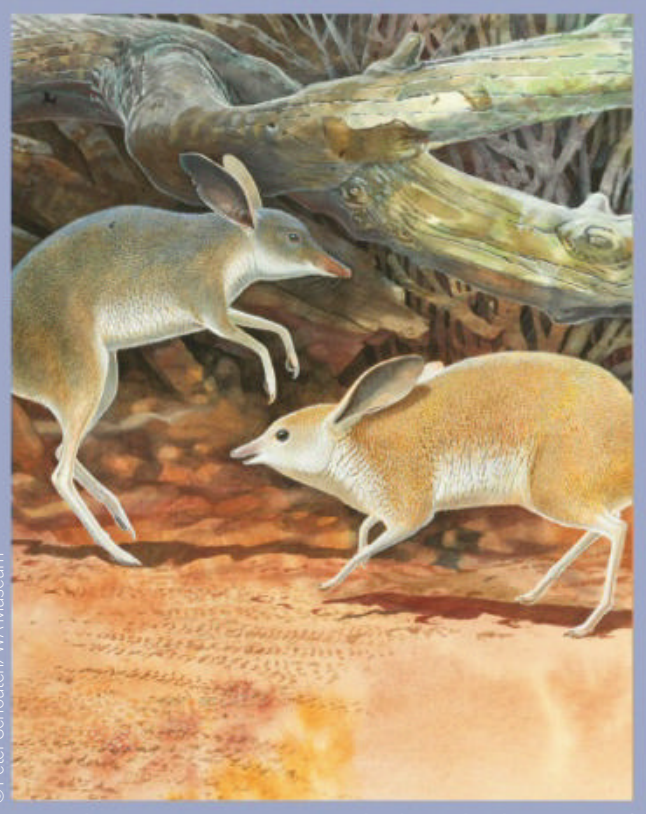
ANIMALS

Extinct 'pig-footed bandicoot' discovered

Words by **Brandon Specktor**

Pig-footed bandicoots are long-eared, long-tailed herbivores that once scurried about the sandy, arid stretches of central and western Australia for tens of thousands of years, before going extinct in the 1950s. With a body mass of about 600 grams and a length of around 26 centimetres, these mammals are considered to be among the smallest grazing animals that ever lived, according to the authors of a recent study.

Researchers from the Natural History Museum in London and the Western Australian Museum analysed 29 dead specimens, taking meticulous bone measurements and comparing DNA samples collected in the 1940s. The results revealed that these pig-footed bandicoot specimens represented two distinct species; previously, researchers thought there was only one. The newly described species, named *Chaeropus yirratji* after a local aboriginal name for the creature, has larger hind feet and a longer tail than its better-studied cousin *Chaeropus ecaudatus*, and may have had different grazing behaviour, according to the study's researchers.



© Peter Schouten/WA Museum

Two Chaeropus yirratji, a newly described species of pig-footed bandicoot

Imagery captured by Sentinel-1 on 19 March shows the extent of flooding (depicted in red) around Beira, Mozambique, after Cyclone Idai made landfall

© ESA

PLANET

Stormy 'inland oceans' seen from space

Words by **Megan Gannon**

A deadly cyclone that hit southern Africa left extensive flooding that looked like 'inland oceans' in images taken from space just days after the storm made landfall.

Sentinel-1, a satellite mission that's part of the ESA's Earth-observation programme Copernicus, captured imagery last month that showed far-reaching floodwaters around Mozambique's town of Beira on the coast of the Indian Ocean.

Cyclone Idai could turn out to be "one of the worst weather-related disasters" in the southern hemisphere, said Clare Nullis, spokesperson for the World Meteorological Organization. In Mozambique, at least 1,000 people are feared dead and tens of thousands have lost their homes, according to the United Nations, after the cyclone made landfall on 14 March, bringing heavy rainfall, a storm surge and strong winds of up to 170 kilometres per hour.

Sentinel-1 is tasked with, in part, mapping flooded areas – like the recent flooding in the US Midwest – to help relief efforts in such situations. According to the European Space Agency, the images acquired before and after the storm offer immediate information to first responders on the extent of flooding and the location of the affected areas. Eventually, satellite data could also be used to assess environmental and property damage.

The first Sentinel-1 satellite launched in 2014, and the second launched in 2015. The pair of polar-orbiting satellites have radar instruments that can 'see' in the dark, as well as through clouds and rain.

Molecular 'thermal capillary waves' have been found to bring two water droplets together

© Getty

STRANGE NEWS

Supercomputer solves mystery of merging water droplets

Words by **Rafi Letzter**

A team of British physicists and mathematicians have used a supercomputer to uncover the hidden truth of how water droplets merge and stick together. Published in the journal *Physical Review Letters*, a new simulation modelled two equally sized droplets of pure water in space, down to the level of individual water molecules. As the droplets got closer together, tiny, ultrafast waves formed on the droplets' surfaces. The random motions of the water molecules, called 'thermal fluctuations', made individual molecules jump and dance towards one another.

Researchers call this surface rippling effect from the thermal fluctuations of the molecules 'thermal capillary waves'. The ripples are too small and fast for any natural experiment to spot. But the simulation showed that the waves reach out to one another, forming the leading edge of the nearing water droplets. The surface tension of the droplets (the cohesive force that keeps the droplets in their shape) suppresses the waves, but they're still present and form the leading edge of the droplets as they draw near.

Eventually, the researchers found, the waves touch, forming bridges between the droplets. And once a single bridge has formed, surface tension gets to work, sealing more ripples together "like the zip on a jacket," as the researchers described. The researchers simulated about 5 million water molecules, forming two drops about four millimetres wide. The whole merging is over in a few nanoseconds at that scale – too fast for any human camera to catch, they wrote.

Understanding this behaviour is important, they said, because it could help to explain the behaviour of water inside clouds or in machines designed to condense water out of the air.

The Hubble Space Telescope captured this image of a galaxy called Messier 49, which contains about 200 billion stars

The Hubble Space Telescope also captured this sharp image of Messier 28

© ESA

SPACE

Hubble snaps 200 billion stars

Words by **Meghan Bartels**

Two incredible new images from the Hubble Space Telescope show galaxies in all their shining glory. The first image, of a galaxy called Messier 49, includes 200 billion stars, although there's no way to pick out most of the individual pinpricks of light within the image. Most of the stars within this elliptical galaxy are about 6 billion years old, and those within its 6,000-odd globular star cluster are even older. And then there's the supermassive black hole at the heart of Messier 49, which contains the mass of 500 million Suns. It's all quite a lot to fit into just one image, even an image of an object 56 million light years away.

Hubble produces very sharp images, like this picture of the stunning globular star cluster Messier 28, which looks like a smear of light near the constellation Sagittarius when viewed from Earth. Messier 28 is much closer than Messier 49, at just 18,000 light years away. Unburdened by atmospheric interference, Hubble can pick out Messier 28's stars in stunning detail.

Physicists resolved a decades-long mystery by describing how quickly a particle can pass through a barrier

TECH

Quantum particles can move through walls

Words by **Mindy Weisberger**

At the subatomic level, particles can fly through seemingly impassable barriers like ghosts. For decades, physicists have wondered just how long this so-called quantum tunnelling takes place. Now, after a three-year investigation, an international team of theoretical physicists have an answer. They measured a tunnelling electron from a hydrogen atom and found that its passage was practically instantaneous, according to a recent study.

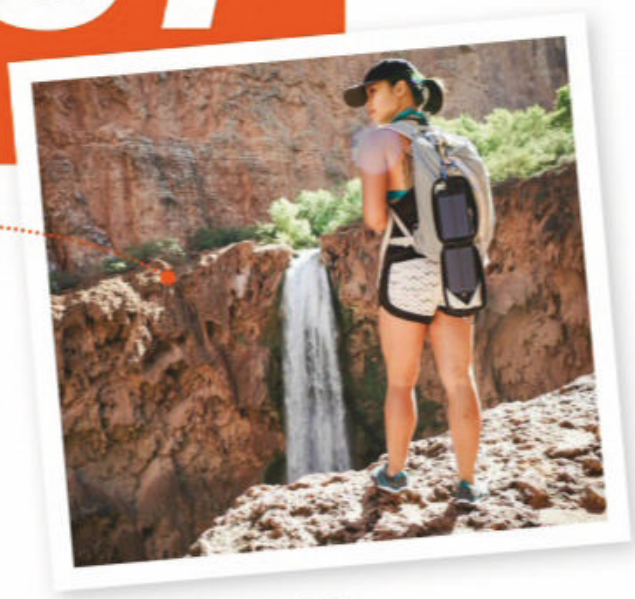
The researchers used an optical timekeeping device called an 'attoclock' – ultrashort, polarised light pulses capable of measuring electrons' movements to the attosecond, or a billionth of a billionth of a second. Their attoclock bathed hydrogen atoms in light at a rate of 1,000 pulses per second, which ionised the atoms so that their electrons could escape through a barrier. A reaction microscope on the other side of a barrier measured the electrons' momentum when it emerged.

The reaction microscope detects energy levels in a charged particle after it interacts with the light pulse from the attoclock, "and from that we can infer the time it took to go through the barrier," Robert Sang, an experimental quantum physicist and professor at Griffith University in Australia, told **Live Science**. "The precision that we could measure this to was 1.8 attoseconds. We were able to conclude that the tunnelling must be less than 1.8 attoseconds" – near instantly, he added.

Though the measuring system was complex, the atom used in the researchers' experiments was simple – atomic hydrogen, which contains just one electron. Earlier experiments conducted by other researchers used atoms that contained two or more electrons, such as helium, argon and krypton, according to the study. Because freed electrons can interact with each other, those interactions can affect particles' tunnelling times. That could explain why prior studies' estimates were longer than in the new study by tens of attoseconds, Sang explained. The simplicity of hydrogen's atomic structure allowed the researchers to calibrate their experiments with an accuracy that was out of reach in prior attempts, creating a benchmark against which other tunnelling particles can now be measured, the study's researchers reported.

WISH LIST

The latest **camping** tech



© Powertraveller

Powertraveller Solar Adventurer

■ Price: **£74 / approx. $100**
powertraveller.com

Gadgets can be an excellent addition to any outdoor venture, but keeping them charged can be difficult. The Solar Adventurer, however, can solve your power problems with help from the Sun. Weighing only 265 grams, this portable dual solar panel charger has a five-volt, 600-milliamp output, incorporating a 3,500-milliamp-hour internal lithium polymer battery. Capable of completely charging a smartphone one to two times, the Solar Adventurer is a great way to stay connected while in the wilderness.

© AKASO

AKASO EK7000 Pro

■ Price: **£79.99 / $74.99**
akaso.net

Taking 4K snapshots, this compact camera is the perfect companion for any outdoor activity. Picture perfect, the EK7000 has in-built image stabilisation to create smooth videos at 1080P/60fps. This pocket-sized professional can also face off against wild weather and plunge to the watery depths of up to 40 metres, thanks to the new and improved waterproof case.

© goTenna

goTenna MESH

■ Price: **approx. £140 / $179**
gotenna.com

Phone signal can be hard to come by when trekking across mountains or hiking through woodlands. That is, of course, unless you've got the goTenna MESH. Through the goTenna app, it can pair with your phone via Bluetooth and enable your phone to communicate with other MESH users at point-to-point ranges of up to 6.4km.

LifeStraw

■ Price: **£25 / $19.95**
lifestraw.com

If you're a keen survivalist or a cautious camper, LifeStraw is the perfect addition to your rucksack. Drinkable water can be limited when trekking through the great outdoors. However, LifeStraw has been created to make any brook, stream or river a viable resource. Thanks to a series of microscopic filters, bacteria and parasites are blocked from entering the mouth when drinking straight from a water source.


© LifeStraw

Outdoor Sports F30

■ Price: **£32.99 / approx. $45**
varta-consumer.com/en

Every camping kit needs a good torch to see you through the night, and Varta's Outdoor Sports F30 is a heavy-duty torch that fits the bill with its five-watt LED. Shock and water resistant, this anodised aluminium torch can handle the elements while still lighting the path ahead for up to 141 metres.

© VARTA

© BioLite

CampStove 2

■ Price: **£129.95 / $129.95**
bioliteenergy.com

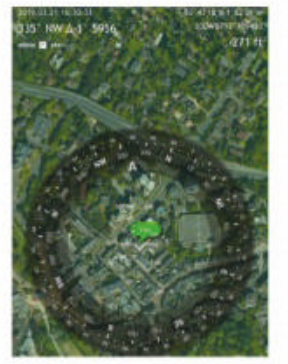
Creating a fire from scratch can be a challenge, as can finding power for your gadgets while out camping. BioLite has created a device to solve both of those problems with the CampStove 2. Turning fire into electricity, the CampStove 2 uses wood fuel and patented combustion technology to create a vortex of flames, while a thermoelectric generator produces three watts of power to charge your devices.

APPS & GAMES

Spyglass

■ Developer: **Happymagenta UAB**

■ Price: **Free / £5.99 / $5.99 / Google Play / App Store**

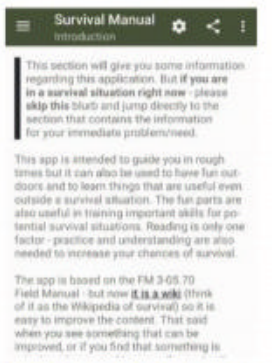


This offline GPS app is the perfect tool for navigation when signal is lost. The app includes a host of features, such as compass, star finder and speedometer.

Offline Survival Manual

■ Developer: **Ligi**

■ Price: **Free / Google Play**



This offline manual offers users tips, advice and instructions on how to survive in the great outdoors. From starting a fire to basic medicine, this app is bursting with useful information.

StarTracker

■ Developer: **PYOPYO Studio**

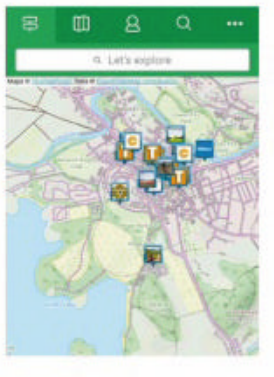
■ Price: **Free / Google Play / App Store**

Get a guided tour of the night sky with this stunning constellation app. Simply hold up your smartphone to the skies and discover the stars and their constellations in real time.

ViewRanger – Hiking Trails & Bike Rides

■ Developer: **Augmentra**

■ Price: **Free / Google Play / App Store**



Discover and explore nearby trails and walks with the ViewRanger app. The app lets you check out other user reviews and suggestions for local GPS-outlined routes and hikes.

ROBOT SURGEON

MEET THE VR, AR AND MACHINE INNOVATIONS THAT ARE REVOLUTIONISING OUR HOSPITALS

Words by **James Horton**

The field of surgery perhaps relies more on technological innovation than any other medical practice. Yet during the Neolithic period, the final era of the Stone Age, surgery was already taking place. Trephining – where a hole would be made into the skull – was used as a proposed treatment for an ailment that still remains a mystery to us today – although the ancient Egyptians would later use the same procedure to treat migraines. Remarkably, some individuals survived this treatment long enough to undergo it a second time!

As with many things in the Western world, our understanding of surgery was bolstered by the ancient Greeks, who performed autopsies to learn about anatomy and helped the living by setting broken bones, 'bleeding' their patients, performing amputations and even draining fluid from lungs. The advanced Islamic world of circa 900CE would go on to produce books on ear, nose and throat surgery and several other subjects. But without anaesthetic, antiseptics and advanced surgical equipment, these practices remained extremely dangerous – and an understandably terrifying prospect for a patient.

By the Middle Ages Europeans had at least made tentative advances in anaesthetics. Unfortunately, the concentrations of herbs and alcohol used for this purpose were about as dangerous as the surgery. They were so powerful that many patients died on the operating table before the surgeon had even started the procedure. Surgeons of this time were an interesting group, as they were mostly barbers by trade; these barber-surgeons would pull a tooth, set a bone or even perform an amputation if the need arose.

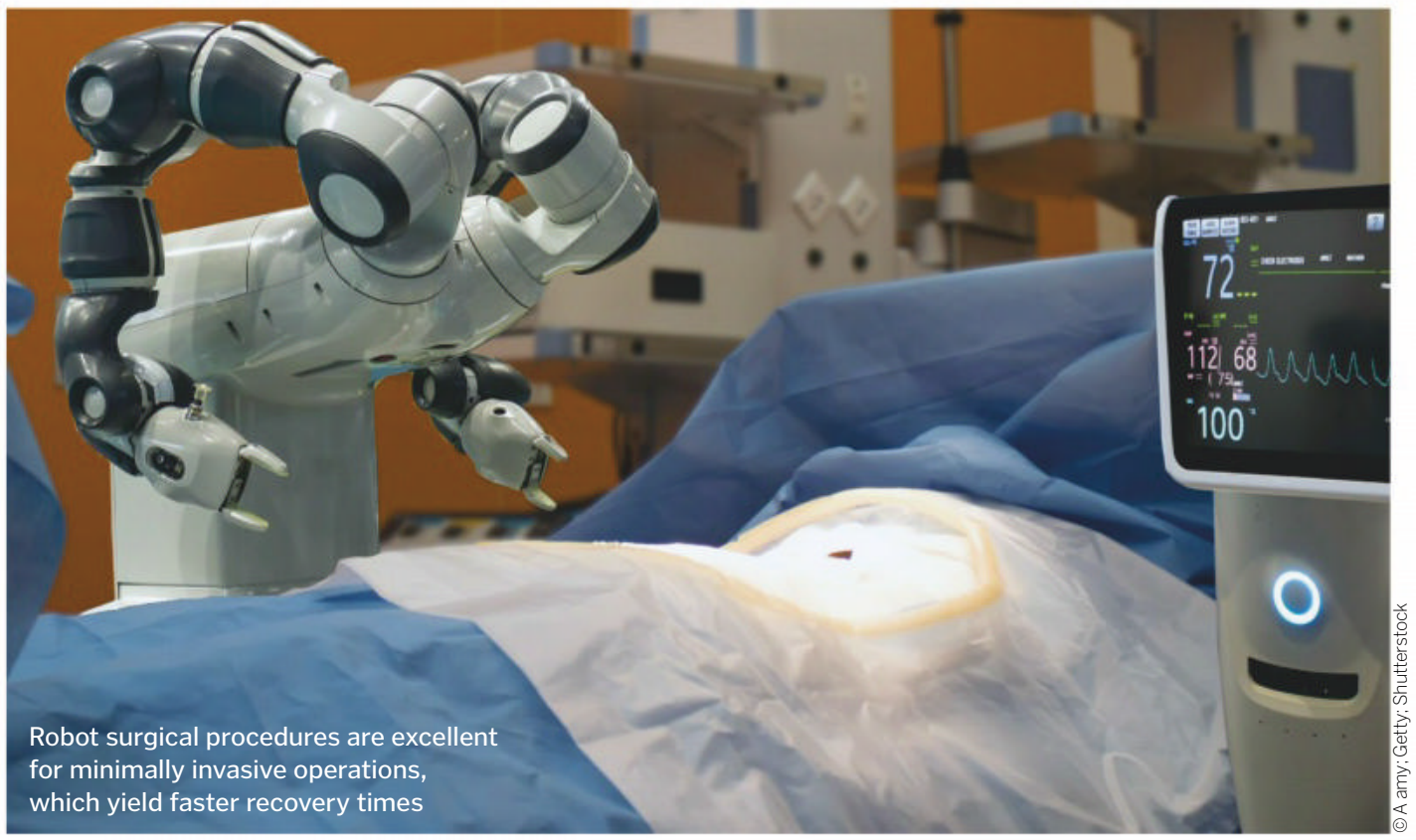
It would take until the 1800s, once the Age of Enlightenment had driven new innovations in science and technology, that an anaesthetic gas would find widespread use. Later that same century we also came to understand germ theory and how to prevent infection following surgery – the basis of modern infection control.

This exponential progress would continue into the 20th century as antibiotics, blood transfusions and X-rays would all increase the safety and effectiveness of surgery. By the turn of the millennium, with our then-comprehensive knowledge of surgery, it would have been easy to believe that little potential remained for future progress. By then people were not only undergoing routine surgery for life-saving operations but also to improve their quality of life, or even just for cosmetic purposes. But it seems we were still just getting started.

Advances in software development and robotics hold immense promise for revolutionising surgery, and many are already making their way into the clinic. These technologies will be found in nearly every corner of the surgical practice, from training future surgeons to conducting a complex procedure.

Let's start at the beginning. Imagine you're a budding surgeon who's itching to get some insight into your chosen profession. The standard process for this would have you peering over an experienced surgeon's shoulder, sometimes travelling far afield to visit an expert based at a distant hospital. But in 2016 VR

> *"Advances in software development and robotics hold immense promise for surgery"*



Robot surgical procedures are excellent for minimally invasive operations, which yield faster recovery times

(virtual reality) was first revealed to be an amazing technology for sharing an immersive view of a surgeon's work in real time. Surgeon Shafi Ahmed performed a live, 360-degree broadcast of a tumour-removal operation. Unlike video footage, VR enables surgical tutees to survey their surroundings, check in on other members of the surgical team and begin to imagine themselves filling the practising surgeon's shoes.

With theoretical knowledge sufficiently enhanced, the next step in your next-generation surgical training would be practice. Of course, practising surgery can be a risk-laden affair, but advanced 3D printing can provide much of the benefit with none of the risk. Physicians at the University of Rochester Medical Center, New York, successfully converted medical scans into computer generated designs to print artificial organs that look, feel, bleed and have the same mechanical properties as real organs. The aim is for these to enable aspiring surgeons to hone their skills to a high standard before beginning on actual patients. Plus, as an added benefit, 3D-printed models can be used for pre-planning and rehearsing complicated surgeries beforehand, increasing the chance of their success, even by experienced surgeons.

Imagine you're a surgeon and we fast-forward to a day in your operating theatre: you are attempting a complicated procedure, where accurate incisions and expert guidance are paramount. Fortunately, you've graduated from virtual environments to augmented environments, and through your high-tech specs you can see the patient's internal structures mapped onto their body. An external expert from across the globe can see this too, and is offering advice as you conduct the surgery. This augmented reality prospect, which has been championed by Microsoft's HoloLens

Virtual reality will play a role in training the surgeons of tomorrow

Seeing inside the patient

All surgeries benefit from making as accurate and small incisions as possible, but in some instances – such as spinal surgery – this accuracy becomes imperative. A pioneering new surgical technology called OpenSight couples digital models based on patient scans with augmented reality HoloLens technology to paste a patient's internal structures over their skin in real time. The digital model moves with the surgeon, providing both 2D images and 3D projections of the internal organs and tissues. This helps the surgical team to assess the patient, pre-plan the procedure in detail and make precise incisions when the operation begins.

OpenSight and HoloLens technology gives surgeons a detailed view of the patient's interior

Preparing for AR surgery

Step by step, how medical practitioners are able to see through our skin during an operation

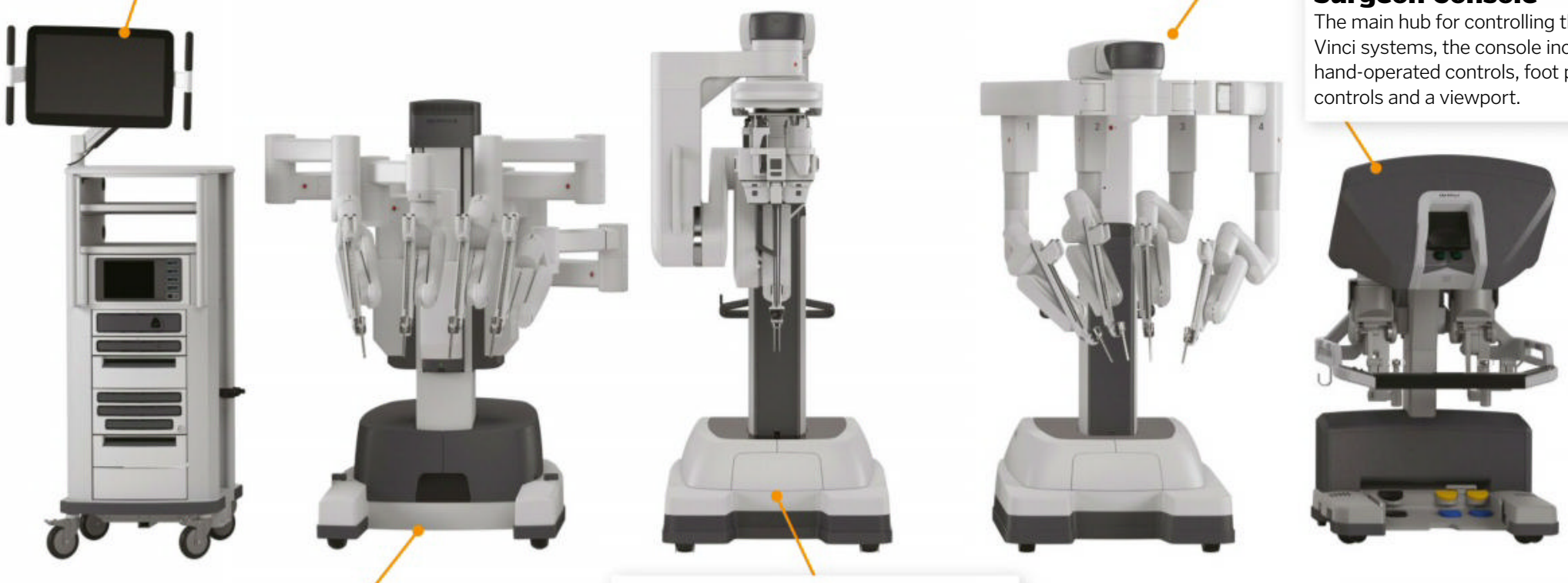
1 Scanning the body
The patient first undergoes a CT scan that captures the positions of their bones, blood vessels, connective tissues, muscles and fat.

2 Converting the scan
An algorithm pores through the scan data and creates a set of polygonal models and digital images that the surgeon's HoloLens can use.

3 Mapping the model
The generated data is mapped onto the patient, enabling the surgeon to see a digital version of the patient's interior during surgery.

The da Vinci devices

Uncover the array of surgical systems available to today's top surgeons



Vision Cart
Used by other members of the surgical team to keep up to date on progress via live-streaming video footage.

The da Vinci SP
A single robotic arm hosting a 3D-HD camera and three multi-jointed instruments can be used for single-point-of-entry procedures.

Surgeon Console
The main hub for controlling the da Vinci systems, the console includes hand-operated controls, foot pedal controls and a viewport.

The da Vinci X
The little brother to the Xi, this system is equipped with modular components and can be upgraded to suit the needs of the operating theatre.

The da Vinci Xi
Equipped to handle a slew of complex procedures, the Xi has advanced hardware and software and can even reposition the operating table during surgery.

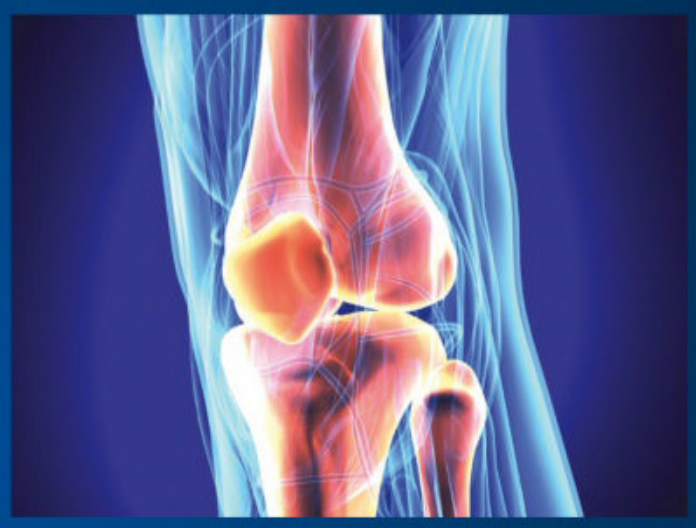
technology, grants the surgeon super-human vision. Additionally, the interconnectivity between surgical teams around the world means that expertise can be shared more equally between hospitals in poorer and wealthier areas.

There are some procedures, however, where even augmented reality-equipped surgeons will be surpassed by those using robotics to enhance their precision in the operating theatre. Established robotic systems, such as the da Vinci Surgical System explored in this feature, are capable of conducting minimally invasive procedures that are largely unmatched by human hands. With improved dexterity, a multitude of arms and internal 3D views, robotics unlocks new possibilities in surgeries that were previously inhibited by a surgeon's limited view and restricted range of motion.

As with all technologies, surgical robotics is being increasingly miniaturised to help with implementation in an array of operating theatres and to tackle even more precise procedures. One concept that meets these aims is the Axsis design, a machine that uses flexible arms with pincers on their ends to tackle eye cataract

Miniature, flexible robotic systems are being developed to treat the sensitive surface of the eye

AR technology is useful for both planning and performing surgery



4 Refining details
A mesh-processing step boosts the accuracy of the digital model, meaning the surgeon can be confident about the interior tissue's position.

5 AR surgery
The surgeon wears a HoloLens during surgery, showing them the locations of tissues and structures.

Welcome to AR theatre

How augmented reality will enhance a surgeon's ability to perform life-saving operations

A guiding hand
External surgical experts can wirelessly interact with the ongoing surgery from afar and offer advice through AR.

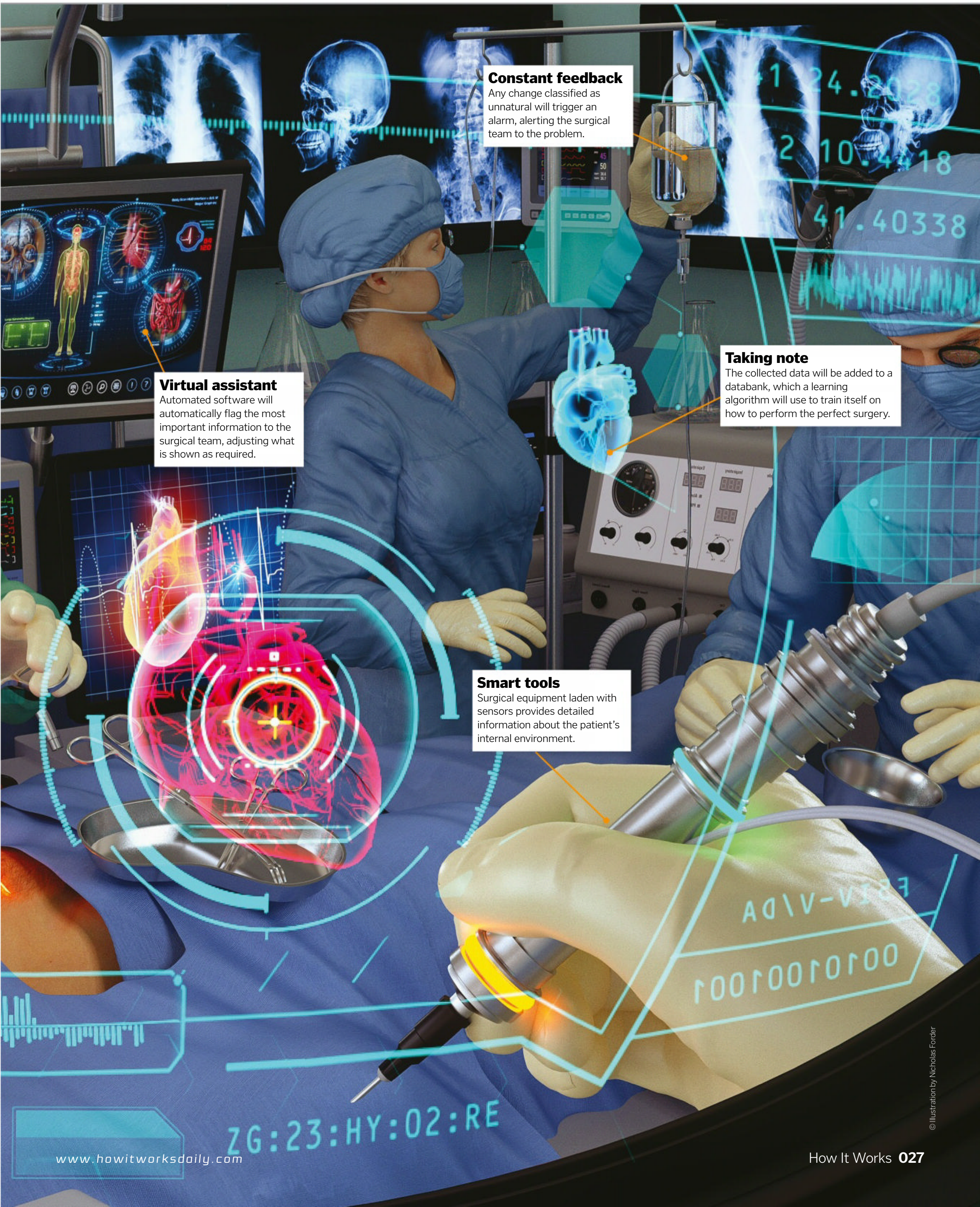
Sensory insight
Information is relayed from the surgical apparatus to the surgeon's head display, allowing them to make necessary adjustments immediately.

Voice control
Simple voice commands can be used to clear the surgeon's augmented reality display.

Learning templates
The data collected during the surgery will also be used to create realistic training scenarios for junior surgeons.

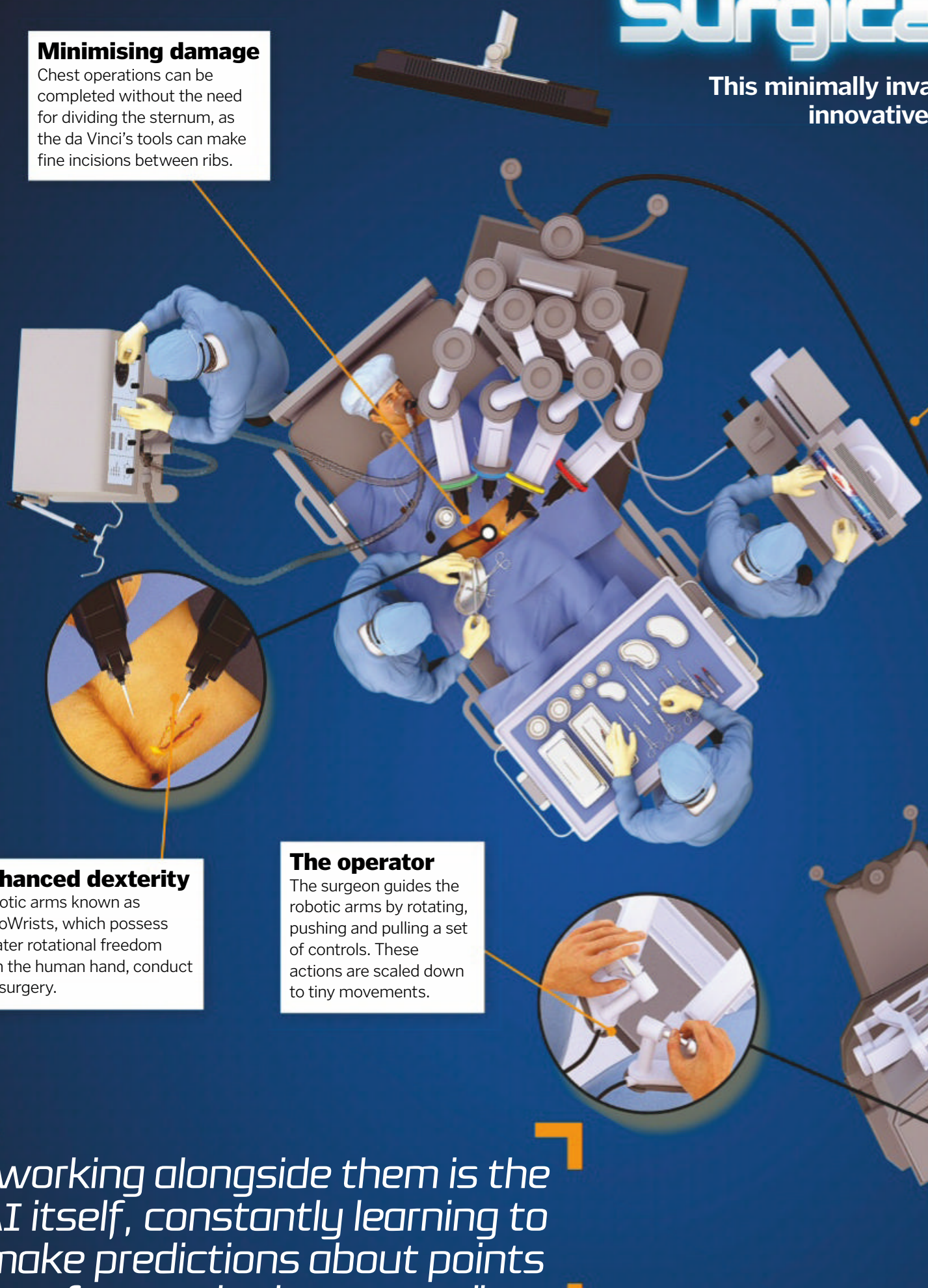
Knowing the landscape
The patient's interior will be mapped onto the surgeon's head display, helping to guide them on the best place to make an incision.

DID YOU KNOW? *US doctors have tested the possibility of remotely performing surgery with robots 1,900 kilometres away*



The da Vinci Surgical System

This minimally invasive equipment is just as innovative as its namesake



Minimising damage
Chest operations can be completed without the need for dividing the sternum, as the da Vinci's tools can make fine incisions between ribs.

Complete control
The robotic arms are unable to operate without direct input from the surgeon, ensuring the lead medical professional retains full control.

A better view
A three-dimensional, high-definition vision system is enabled by tiny cameras inserted into the patient, enabling the surgeon to operate in extremely fine detail.

Enhanced dexterity
Robotic arms known as EndoWrists, which possess greater rotational freedom than the human hand, conduct the surgery.

The operator
The surgeon guides the robotic arms by rotating, pushing and pulling a set of controls. These actions are scaled down to tiny movements.

New angles, new insight
Foot pedals within the operative console are used to switch the internal viewpoint seen by the surgeon.

"working alongside them is the AI itself, constantly learning to make predictions about points of stress in the system"

$6.4 billion
The estimated value of the surgical robotics market by 2020

4,500+
The number of da Vinci robots worldwide of which over 70 are used in UK hospitals

750,000
The amount of remote clinical encounters facilitated by telehealth network InTouch Health

PARO, an interactive robot modelled on a seal, was designed to comfort patients in recovery

400kg
The weight of medication carried by the nursing assistant TUG robot

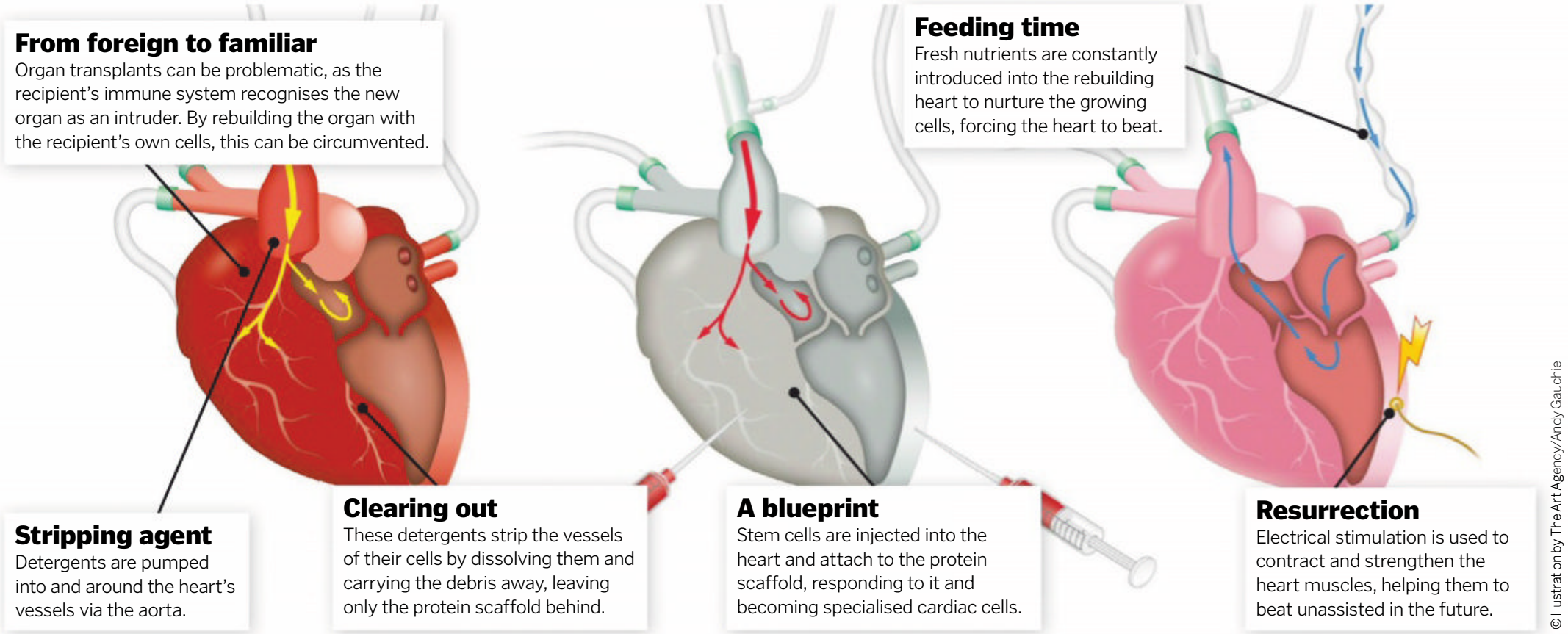
40
The number of times the Robear nursing robot can lift patients each day

The iKnife surgical tool heats tissue to diagnose cancer

Microrobots that can migrate through blood vessels are currently being developed by the Max Planck Society

Retrofitted organs

How surgeons convert donor hearts into replacements suitable for any patient, through bioengineering



From foreign to familiar
Organ transplants can be problematic, as the recipient's immune system recognises the new organ as an intruder. By rebuilding the organ with the recipient's own cells, this can be circumvented.

Stripping agent
Detergents are pumped into and around the heart's vessels via the aorta.

Clearing out
These detergents strip the vessels of their cells by dissolving them and carrying the debris away, leaving only the protein scaffold behind.

A blueprint
Stem cells are injected into the heart and attach to the protein scaffold, responding to it and becoming specialised cardiac cells.

Feeding time
Fresh nutrients are constantly introduced into the rebuilding heart to nurture the growing cells, forcing the heart to beat.

Resurrection
Electrical stimulation is used to contract and strengthen the heart muscles, helping them to beat unassisted in the future.

© Illustration by The Art Agency/Andy Gauchie

surgery. The accuracy of the 1.8mm arms are reinforced by image-guidance software and an artificial intelligence that will advise and inform the medical practitioner during surgery.

The miniature technologies may not stop there. NASA has partnered with medical company Virtual Incision to create a small robot that can be operated remotely by a surgeon for small operations in low gravity. If it's a success, we may find these robots in use on Earth too.

Tools such as Axsis, da Vinci, HoloLens and others are driving the future of surgery to a point where we have better-educated, trained, connected and equipped surgeons than ever before. And like the transformations in surgery that happened throughout the previous century, we can be hopeful that progress of the same scale is on the agenda.

Learn more

Continue to engage with the future of surgery by visiting: **futureofsurgery.rcseng.ac.uk**. This visionary site was pioneered by the Royal College of Surgeons and is the brainchild of 14 surgical experts.

Surgery command centre

We live in an era of big data. In all fields, especially medicine, we are collecting swathes of data aimed at improving patient care. But when handled improperly, this can impair the level of care rather than improve it. To ensure they make the best use of patient data and learn from it, GE Healthcare and the Bradford Royal Infirmary have teamed up to create an AI command centre. Equipped with a wall of analytics showing the most important information, allocated sections for coordinators and a central platform for the supervisor to overview the situation, the command centre seems like it would fit in better at NASA than a hospital. But with this hub of data, the coordination teams can allocate care where it's needed most. Working alongside them is the AI itself, constantly learning from the stream of data to make predictions about stress points in the system, advising the team to act before the problem arises.

Advanced algorithms
Algorithms will assist staff to spot bottlenecks before they occur, helping to prevent issues from arising.

Wall of analytics
This giant display will relay crucial real-time information to the teams in the comannd centre.

Specified teams
Up to 20 staff at a time will focus on specific areas, such as bed management, staff coordination and OR management.

Coordination
With all the teams together and fed the same information, staff can coordinate more effectively.

Better care
The new command centre will lead to a more efficient and effective operation at the 800-bed hospital.

© Illustration by Ed Crooks

Inside your foot

One of the first things we learn to do is walk, but how exactly do we move from heel to toe?

Each foot is comprised of 26 bones

With every step we take, a set of biological cogs are set in motion, enabling us to get from A to B.

The action of walking may seem pretty straightforward, but actually our feet are made up of a complex and unique arrangement of bones, tendons and ligaments.

Tendons are the rigid and fibrous tissues that attach muscles to a bone. In the case of moving the foot, the main tendon engaged is the Achilles tendon, which connects your calf muscle to your hindfoot bone, called the calcaneus.

Ligaments are bands of elastic connective tissue that bridge the gap between bones. In order for the muscles connecting the foot to contract and relax – the basis of movement – they require stimulation from nerves that feed into the foot, like the tibial nerve.

A type of connective fibrous tissue, known as the plantar fascia, is responsible for putting the spring in your step. Spanning the length of your foot, this tissue acts as a springboard. As we lift our foot at the beginning of a step, the tissue becomes taut due to our toes lifting upwards. As the foot is returned to the ground, the tension in the tissue increases further, storing energy like a spring. That energy is released in the next step, giving our footsteps their bounce.

Artificial limb

In recreating the human foot, some prosthetic feet have been designed to replicate its natural physics. As the plantar fascia acts as the energy store for a biological foot, many prosthetic carbon fibre designs mimic the same function. When the wearer applies weight to the prosthetic, the carbon compresses, storing energy. When the foot is rolled to make a step, the energy is released, propelling it forward. Shock absorbers and an artificial multi-axial ankle are also incorporated to replicate the natural movement of the foot. This allows the wearer to roll the foot in the desired direction while remaining stable.

Prosthetic feet have been designed to replicate the natural function of the foot

Heel to toe

The tissues and bones responsible for each stride

Talus bone
This bone is connected to the lower leg's tibia and fibula, enabling us to move from the ankle down.

Tarsal bone
The tarsal is made up of five midfoot bones to form the foot's arch. This configuration of bones is locked in place while you stand still, and separates during a step.

Joints
There are several joints connecting bones for flexibility, including the metatarsophalangeal joint, enabling the foot to move each toe.

Calcaneus
The largest bone in the foot, forming the foot's heel. The calcaneus is also vital for foot strength and balance.

Plantar fascia
This is the longest ligament and the one responsible for putting a spring in our step.

Metatarsals and phalanges
The forefoot's five metatarsal bones lead to the phalanges that make up the foot's toes. Each toe has three phalanges, with the exception of the big toe, which only has two.

AIRFIX

QUICK BUILD

J6018 RAF Red Arrows Hawk

A Model Aircraft
THE RAF RED ARROWS HAWK

1	11.85 m	9.39 m
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The British Aerospace Hawk is one of the most important British jets. Having first flown as the Hawker Siddeley Hawk in Surrey in 1974 the Hawk is still in production in the UK today and is sold to many different countries all over the world. The Hawk is considered a "low-cost" combat aircraft, in 2003 one would've reportedly cost you approximately £18 million!

Without doubt, the most famous of the 1000+ BAe Hawks produced are the aircraft which wear the distinctive colours of the Royal Air Force Aerobatic Team 'The Red Arrows', arguably the world's best and certainly the most famous aerobatic display team.

The Red Arrows have been performing their thrilling displays to audiences all over the world since 1965, fulfilling the role of Britain's most effective flying ambassadors wherever they appear. To join the Red Arrows display team candidates have to have completed a front line tour as a Royal Air Force pilot, have a minimum of 1500 flying hours and be assessed as "above average" in their current RAF flying role. A maximum of three new pilots are chosen each year so the pilots of the Red Arrows really are the best of the best!

The Red Arrows have appeared in almost 5,000 displays in over 50 countries. A global television audience of over one billion people watched the flypast they performed at the London 2012 Olympic Games Opening Ceremony. The Hawks of the Red Arrows really are amongst the most famous aeroplanes in the history of aviation.

The Red Arrows Hawk is a British icon and you can recreate your own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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Refraction, rainbows and mirages

Amazing things happen when beams of light bend

Everyone knows that nothing moves faster than the speed of light, but light doesn't always travel at its limit. It only reaches the dizzying speed of 299,792,458 metres per second in a vacuum. When light travels through any other material, be that a gaseous atmosphere or a glass of water, it interacts with atoms, and that slows it down.

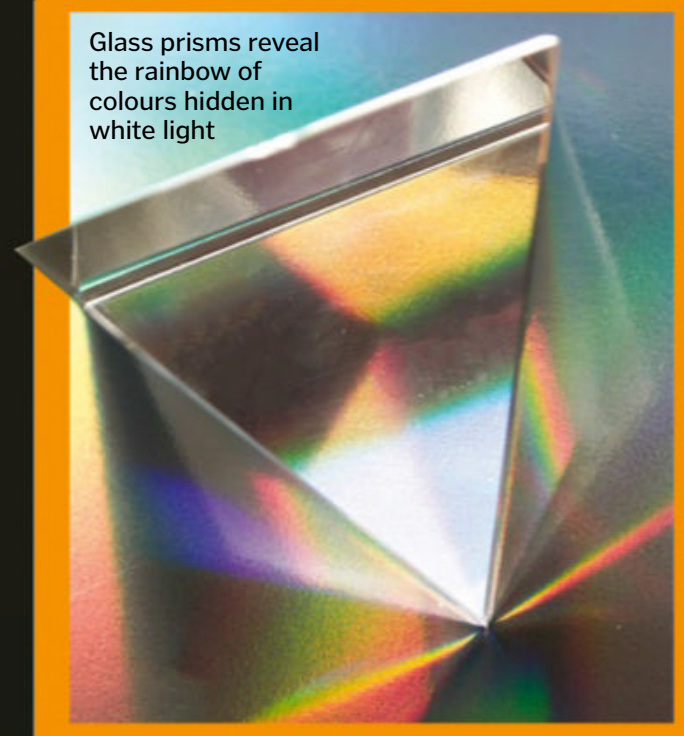
If a beam of light hits a new material head-on, the wavelengths bunch up. They get closer together and the whole beam moves more slowly, but the light keeps moving in a straight line. When a beam hits a new material at an angle, something special happens. The part of the beam that hits first slows down first, and the light starts to bend. This plays tricks on our eyes, creating kinks in our drinking straws and puddles of water on dry desert floors.

Imagine a row of soldiers marching at an angle towards a line. Each soldier will slow down when they reach the line, but they don't all get there at the same time. When the first soldier arrives and adjusts their speed, the others carry on marching, causing the line to become staggered. The same thing happens when light hits a new material at an angle.

The amount the light bends depends on the 'refractive index' of the material it's moving through. This compares the speed of light in the material to the speed of light in a vacuum. For example, a refractive index of 1.5 means that light travels 1.5 times faster in a vacuum than in the material.

Light bends as it travels through these curved water droplets

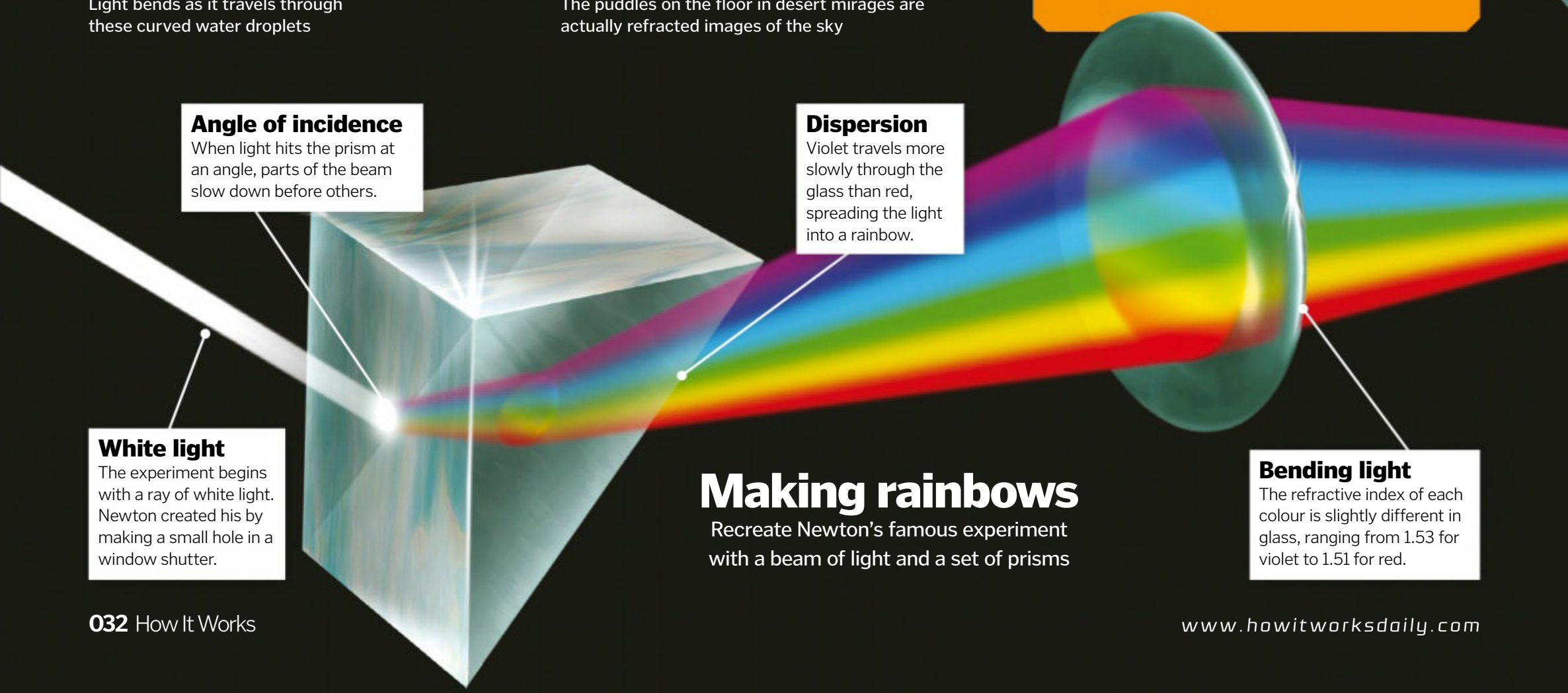
The puddles on the floor in desert mirages are actually refracted images of the sky



Glass prisms reveal the rainbow of colours hidden in white light

Newton's rainbows

It's been more than 300 years since Isaac Newton first tried his prism experiment, but the results are as dazzling as ever. At the time, people thought that colours were mixtures of light and darkness, and that white light was pure. Newton changed how we think about colour by placing a glass prism in a shaft of sunlight. When the light hit the prism at an angle, refraction separated the rays into a rainbow. The colours were always in the same order: red, orange, yellow, green, blue, indigo and violet. To prove that it wasn't the prism creating the colours, Newton put a second prism into the rainbow. Refraction bent the split beam back into a single stream of white light, demonstrating once and for all that white light contains all the colours.



Making rainbows

Recreate Newton's famous experiment with a beam of light and a set of prisms

5 FACTS ABOUT MIRAGES

1 Superior mirage
When warm air sits above cold air, the light bends downwards. This makes objects appear taller than they actually are and allows us to see things beyond the horizon.

2 Inferior mirage
When cold air sits above warm air, the light bends upwards, making the sky appear in puddles on the floor and creating classic desert mirages.

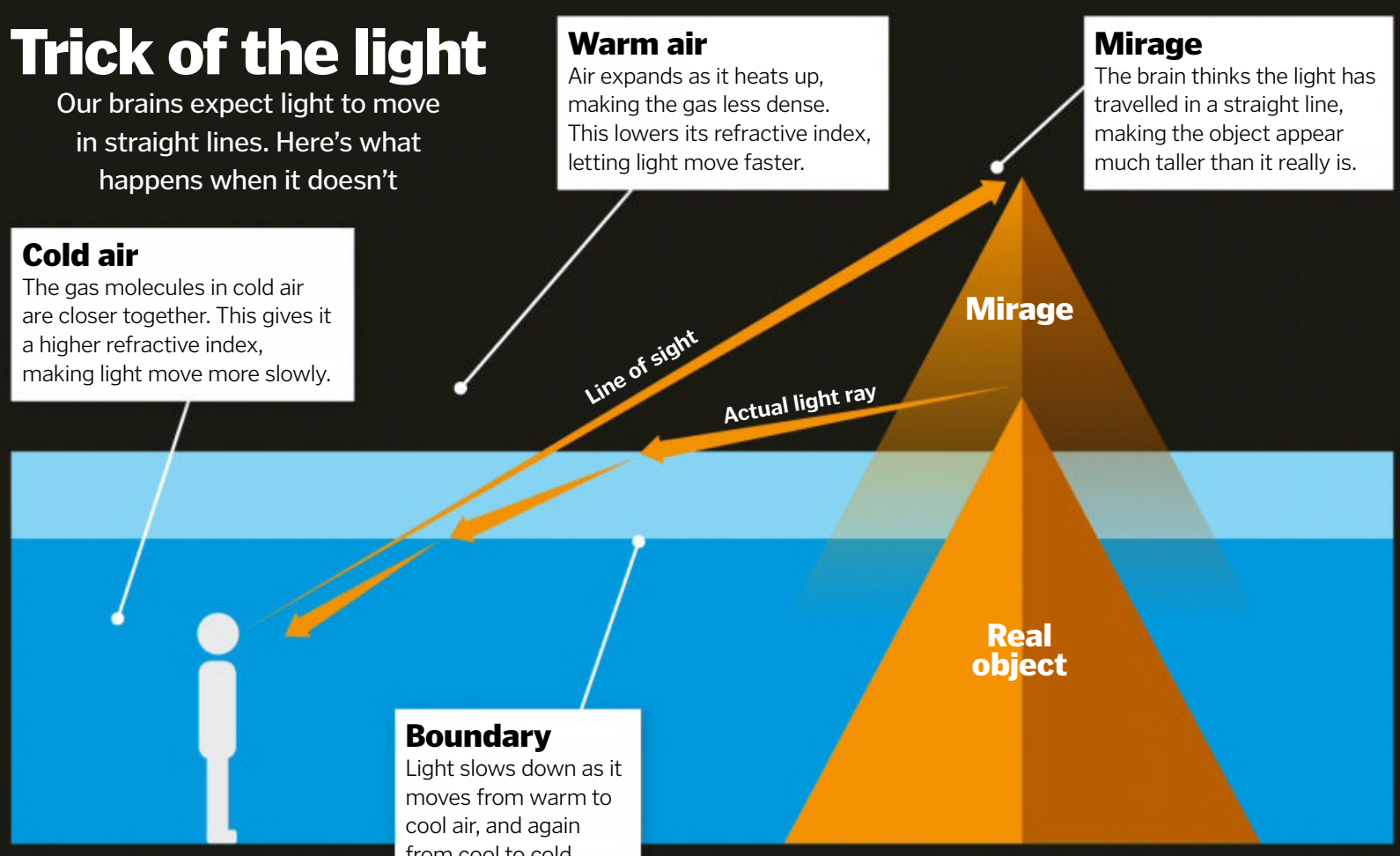
3 Late mirage
When a pocket of warm air blows over cold air, it's called a temperature inversion. When it happens above your eyeline, a strip of the Sun can seem to disappear.

4 Mock mirage
The effect of temperature inversions can change depending on their height. When they happen below your eyeline, they make wobbly horizontal slices through the sunset.

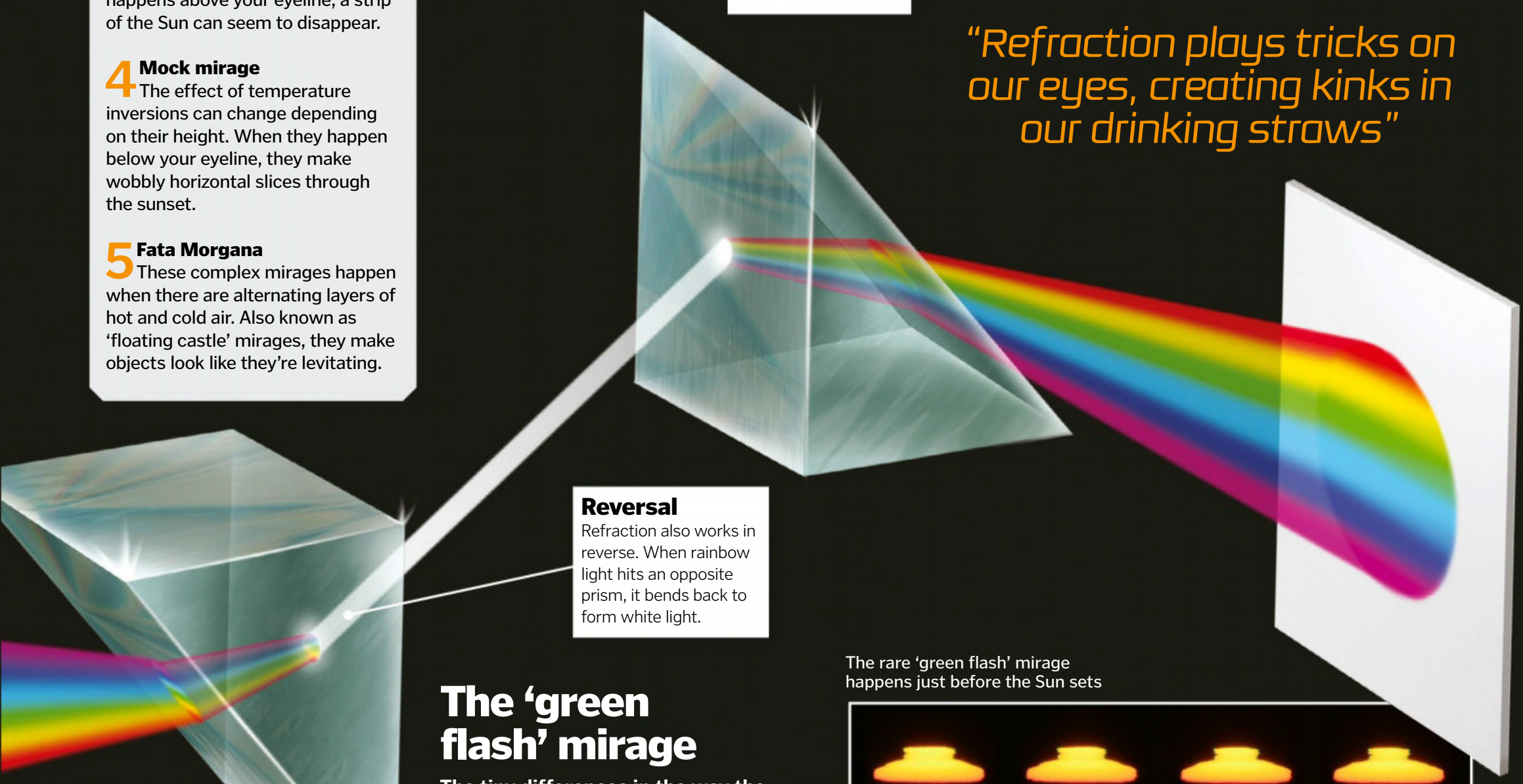
5 Fata Morgana
These complex mirages happen when there are alternating layers of hot and cold air. Also known as 'floating castle' mirages, they make objects look like they're levitating.

Trick of the light

Our brains expect light to move in straight lines. Here's what happens when it doesn't



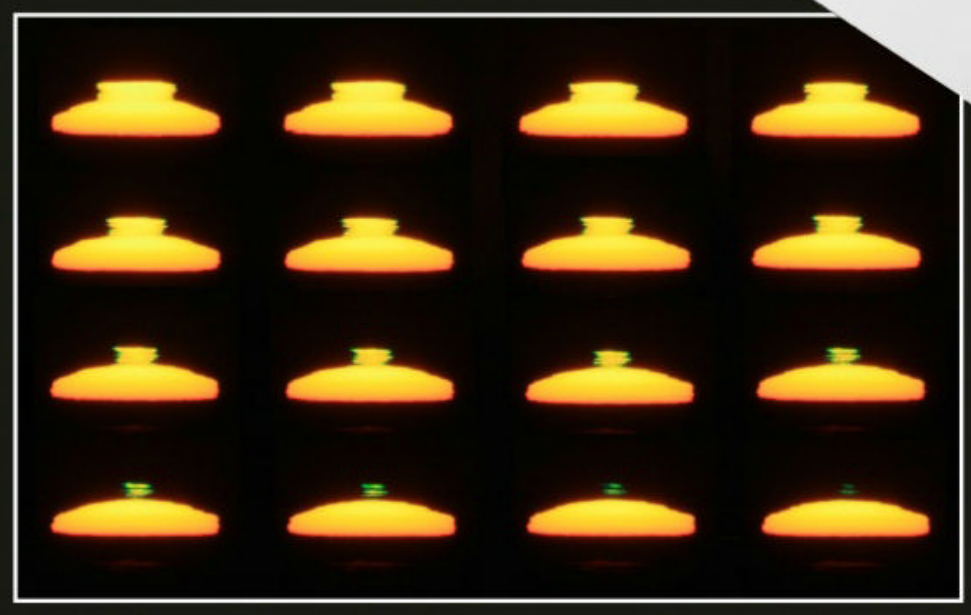
"Refraction plays tricks on our eyes, creating kinks in our drinking straws"



The 'green flash' mirage

The tiny differences in the way the atmosphere refracts different colours of light aren't that noticeable during the day. But as the Sun sets, the effects can be dramatic. When the Sun drops below the horizon, a vibrant 'green flash' mirage can appear in its place. This rare afterimage happens because red light curves less than green light as it moves through the air. After the Sun sets, the red light rapidly disappears over the horizon. But if conditions are right, green light can continue to curve around the Earth for a few beautiful moments.

The rare 'green flash' mirage happens just before the Sun sets



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HOW WE OBSERVE DEEP SPACE

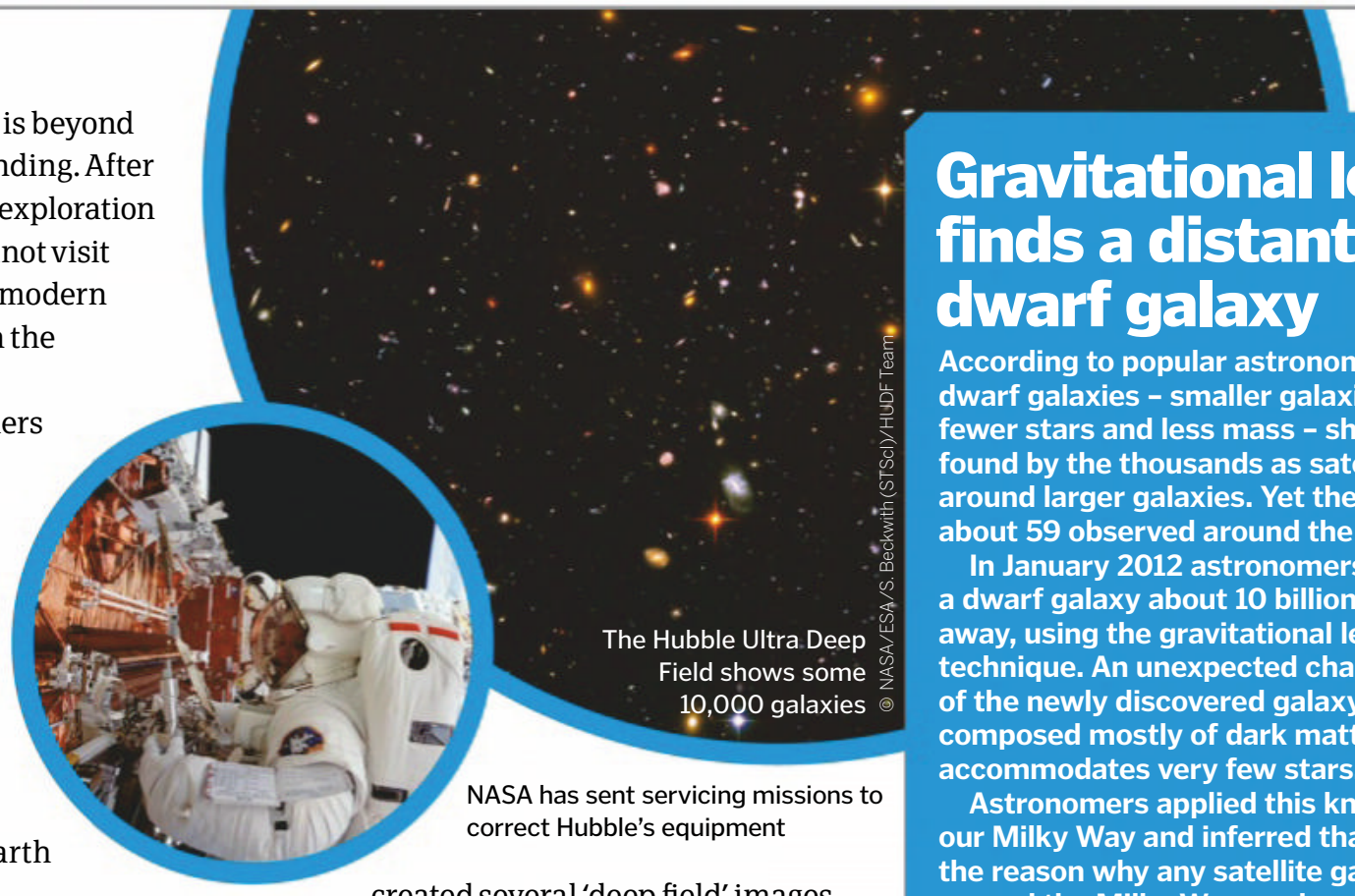
The natural phenomena and inspired methods that allow NASA and ESA to detect the farthest objects in the cosmos

Words by **Lee Cavendish**

It is human nature to wonder what is beyond the limits of our current understanding. After the exploration of Earth came the exploration of the universe, and although we cannot visit objects far beyond our Solar System, modern technology has shown us what lies in the deepest reaches of the cosmos.

The furthest objects that astronomers have observed recently are distant galaxies, as they emit copious amounts of light that provide the best chance of observation at a distance. Light travels at a finite speed – almost 300,000 kilometres per second. This is too fast for the human eye to spot, but because the universe is so big, light leaving a deep-space object might not reach Earth for millions or even billions of years. Astronomers use the term 'light year' as the distance that light can travel in one year, which is almost 10 trillion kilometres.

One of the reasons NASA and ESA created the Hubble Space Telescope was to search for distant objects in the universe. Hubble has created several 'deep field' images, where it observes a patch of apparently black sky and collects as much light from it as possible. After some processing on a computer, the final image shows thousands of galaxies, some of which are the most distant objects in the observable universe.



The Hubble Ultra Deep Field shows some 10,000 galaxies

NASA has sent servicing missions to correct Hubble's equipment

Gravitational lensing finds a distant dwarf galaxy

According to popular astronomy theories, dwarf galaxies – smaller galaxies with fewer stars and less mass – should be found by the thousands as satellites around larger galaxies. Yet there are only about 59 observed around the Milky Way.

In January 2012 astronomers discovered a dwarf galaxy about 10 billion light years away, using the gravitational lensing technique. An unexpected characteristic of the newly discovered galaxy is that it's composed mostly of dark matter and accommodates very few stars.

Astronomers applied this knowledge to our Milky Way and inferred that maybe the reason why any satellite galaxies around the Milky Way are hard to find is because they are mostly comprised of dark matter and so are difficult to detect.

Dwarf galaxies latch onto a larger galaxy's gravity and become its satellite

Hubble's anatomy

This sophisticated space telescope has led to some amazing recent discoveries about the universe

Primary mirror
This is the main, 2.4-metre mirror that collects light from the universe and reflects it to the secondary mirror.

Secondary mirror
This 30-centimetre-diameter mirror directs the light from the primary mirror towards Hubble's instruments to begin deciphering information from the light.

Fine guidance sensors (FGS)
These instruments direct the telescope, with two sensors pointing at the target and the third used for astrometry.

Aperture door
The safety door closes if there is a danger of too much light coming in from the Sun.

Space Telescope Imaging Spectrograph (STIS)
From infrared to ultraviolet, this powerful instrument gathers lots of spectral data about its intended target.

Near Infrared Camera and Multi-Object Spectrometer (NICMOS)
NICMOS analyses the infrared light taken in by a light source, specifically between wavelengths of 800 and 2,500 nanometres.

Advanced Camera for Surveys (ACS)
ACS replaced the Faint Object Camera in 2002 and provides wide-field views of the universe.

Cosmic Origins Spectrograph (COS)
This highly sensitve ultraviolet spectrograph was designed to perform spectroscopy on faint-point sources.

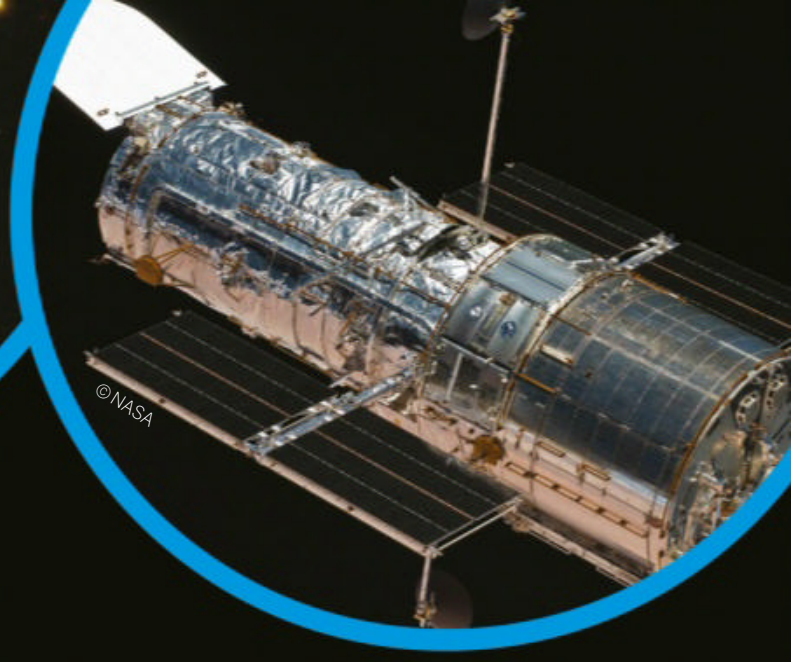
Wide Field Camera 3 (WFC3)
This camera has the capability of observing its targets in multiple wavelengths and has produced some of the most iconic images of the universe.

Astronomers can also learn about the early universe by observing these galaxies. When astronomers discovered the current record-holder for the most distant galaxy, GN-z11, which is seen from Earth as it was 13.4 billion light years ago, it meant that the universe was just 400 million years old when the light left GN-z11 to make its journey across space into Hubble's lens.

Another trick that Hubble uses to observe difficult-to-see and distant objects that might be hiding behind other, brighter objects, is with the help of gravitational lensing. The gravity of enormous galaxy clusters can bend light around them in the same way a glass lens does. This can show astronomers what is happening behind these distant objects.

© NASA/ESA

The galaxy cluster SDSS J1038+4849 appears as a smiley face due to Einstein rings



© NASA

The Hubble Space Telescope was launched into space in April 1990

Seeing into space

1609

Distance 12.5 light minutes

Although Mars has been seen twinkling in the sky for centuries, Italian astronomer Galileo Galilei makes the first telescope observations of the planet in 1609.

1610

Distance 43 light minutes

Turning his attention to another planet, Galileo observes Jupiter and notices four large moons.

March 1781

Distance 160 light minutes

Dimmer than Mars and Saturn, Uranus is still visible to the naked eye. Sir William Herschel announces the planetary discovery in March 1781.

1838

Distance 25 light years

Vega in the constellation Lyra is one of the brightest stars, but its distance isn't measured until astronomers use the parallax method accurately.

1849

Distance 42.2 light years

From 210,000 to 160,000 years ago, Capella was the brightest star in the night sky. Its distance is first measured in 1849.

1912

Distance 28 million light years

The famous Sombrero Galaxy (M104) is the second galaxy, after the Andromeda Galaxy (M31), to have its distance measured using redshift.

1970

Distance 5 billion light years

The quasar 4C 05.34 is observed to have an enormous redshift distance – in fact it is thought at first to be an anomaly.

23 April 2009

Distance 13 billion light years

NASA observes a flash of gamma-ray radiation known as GRB 090423. It lasts only ten seconds, but astronomers can pinpoint its distance.

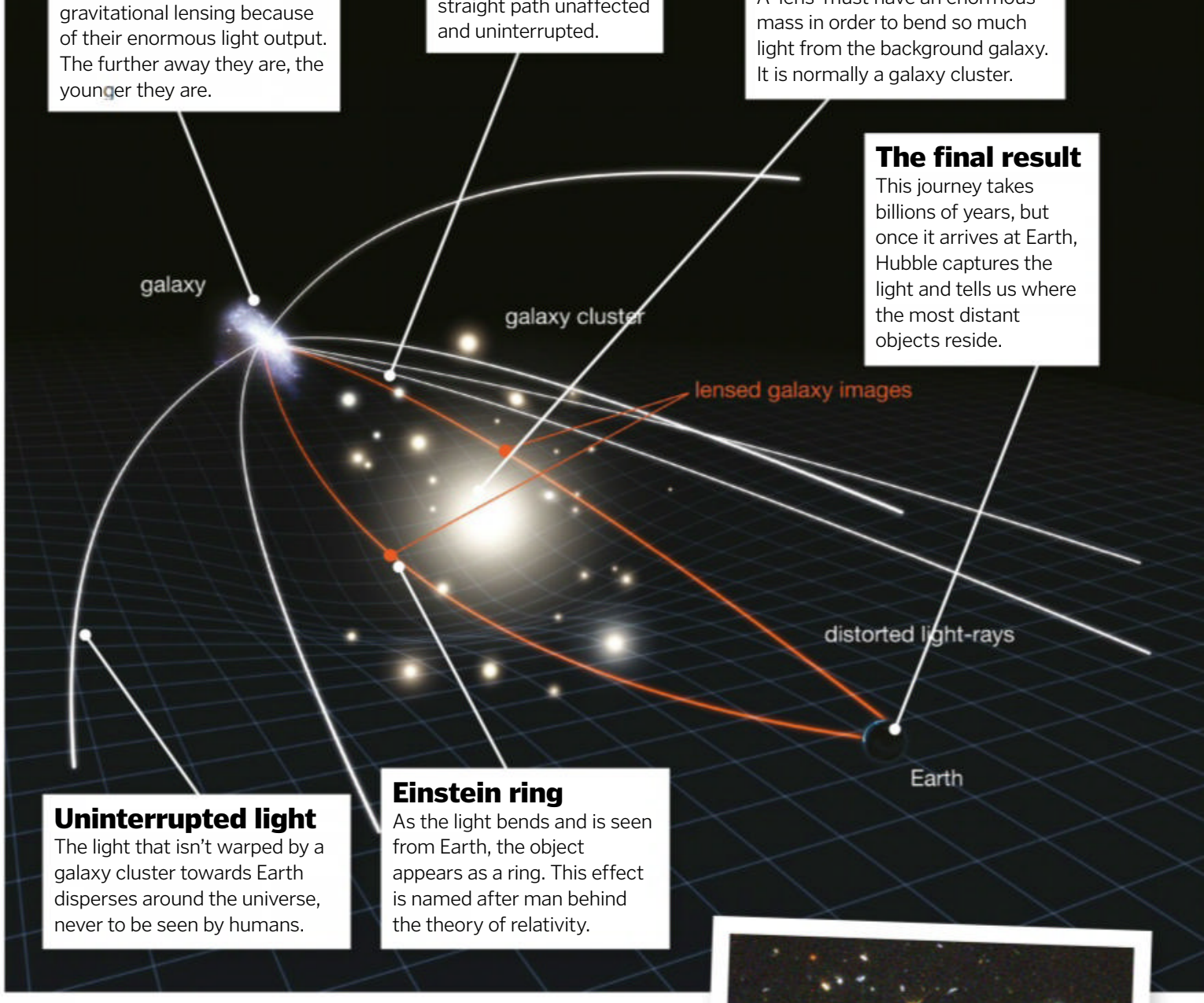
3 March 2016

Distance 13.4 billion light years

GN-z11 is observed using the Hubble Space Telescope, and is seen from when the universe was just 400 million years old.

Cosmic spyglass

Gravitational lensing is a natural phenomenon that brings hidden objects from the background into the foreground



Distant galaxy
Galaxies are normally the type of object discovered with gravitational lensing because of their enormous light output. The further away they are, the younger they are.

The start of light's journey
As the light leaves the galaxy, it travels on a straight path unaffected and uninterrupted.

The galactic lens
A 'lens' must have an enormous mass in order to bend so much light from the background galaxy. It is normally a galaxy cluster.

The final result
This journey takes billions of years, but once it arrives at Earth, Hubble captures the light and tells us where the most distant objects reside.

Uninterrupted light
The light that isn't warped by a galaxy cluster towards Earth disperses around the universe, never to be seen by humans.

Einstein ring
As the light bends and is seen from Earth, the object appears as a ring. This effect is named after man behind the theory of relativity.

The deep space realisation

The gargantuan size of the universe was underscaled until the 1995 Hubble Deep Field (HDF) image was captured. The Hubble team decided to try something new and collect as much light as possible from a narrow patch of sky in the Ursa Major constellation.

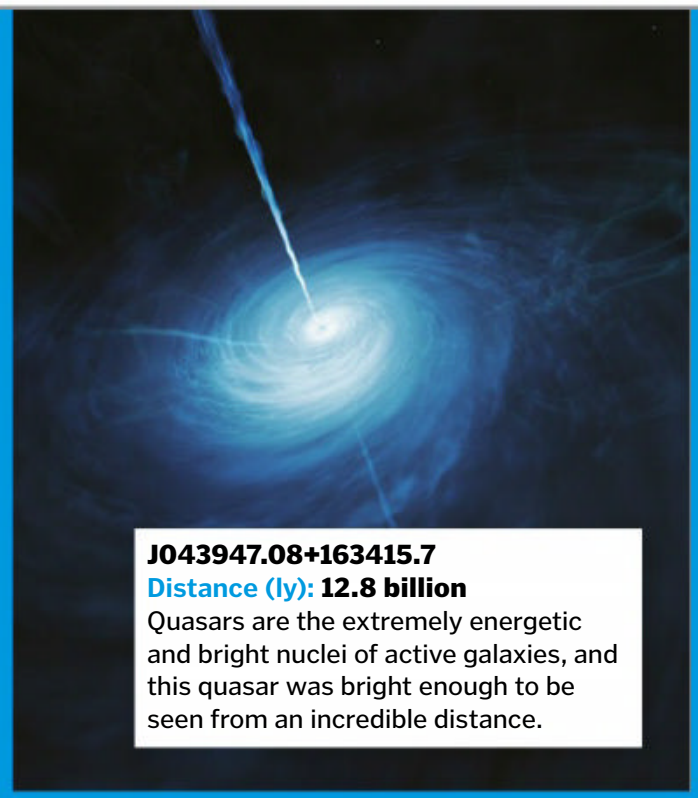
After more than ten days, 100 hours of observation and 342 images later, Hubble produced an image showcasing 3,000 galaxies. This image shattered the perception of how many galaxies there are in the universe and the incredible distances they are from Earth. If you extrapolate the amount of the galaxies seen in this keyhole in the sky, then behind the door of the universe should lie almost 100 billion galaxies – a truly mind-boggling number.

© R.Williams/Hubble Deep Field Team (STScI)/NASA

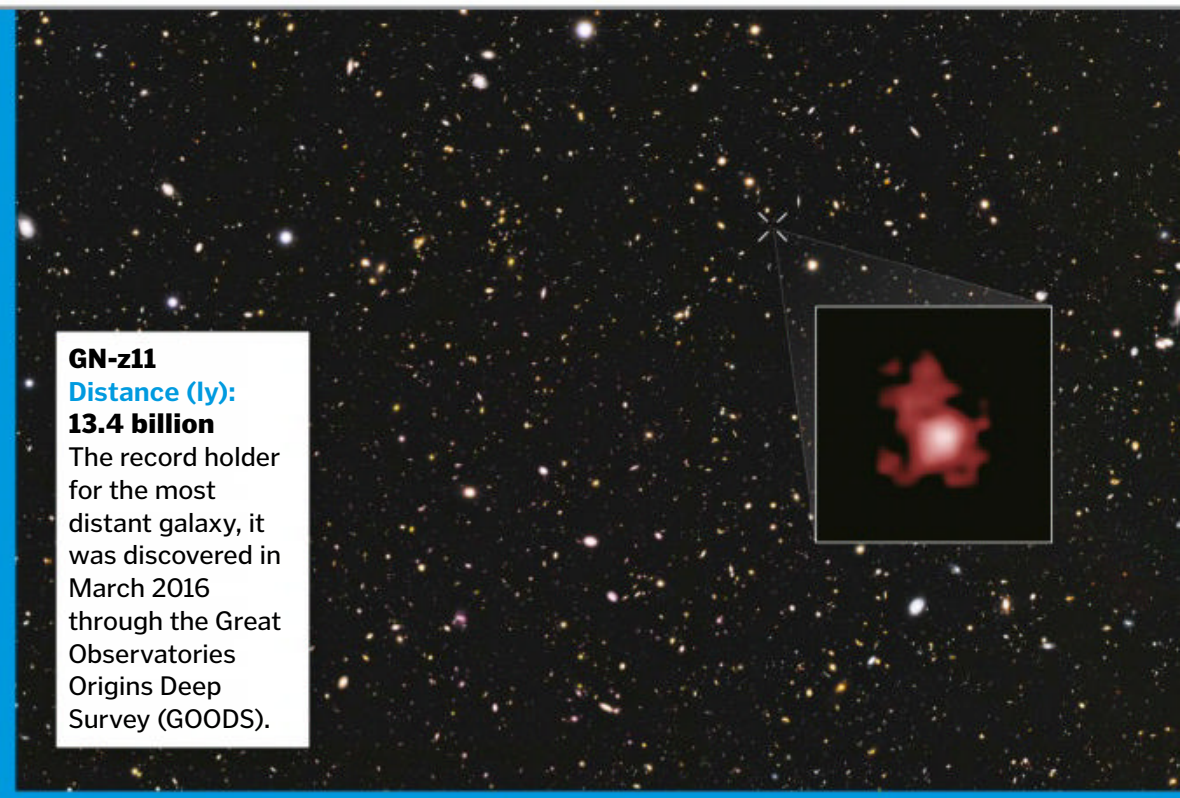
The Hubble Deep Field was observed with the Wide Field and Planetary Camera 2

Deep space scrap book

These images show the deepest and most magnificent astronomical objects that have been observed in the universe so far

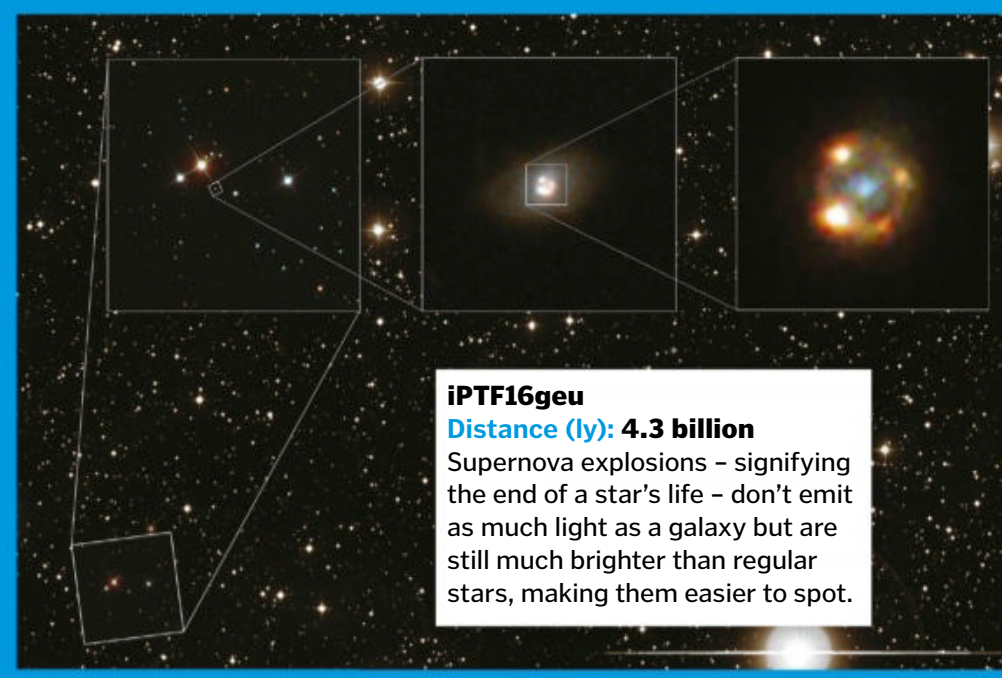


J043947.08+163415.7
Distance (ly): 12.8 billion
Quasars are the extremely energetic and bright nuclei of active galaxies, and this quasar was bright enough to be seen from an incredible distance.

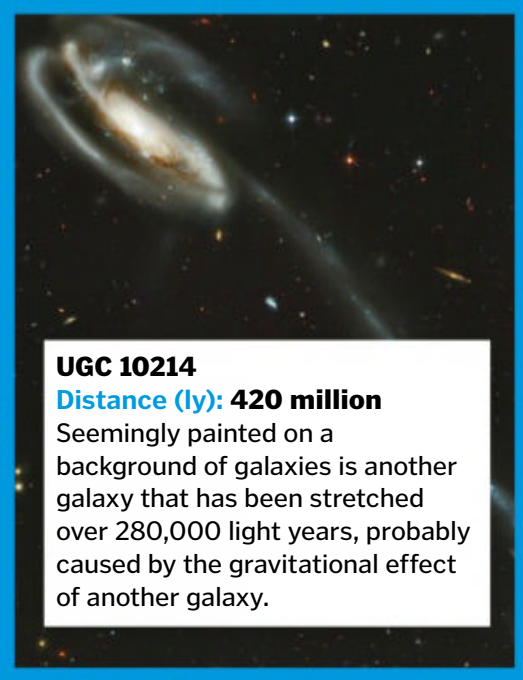


GN-z11
Distance (ly): 13.4 billion
The record holder for the most distant galaxy, it was discovered in March 2016 through the Great Observatories Origins Deep Survey (GOODS).

WISE J224607.55-052634.9
Distance (ly): 12.4 billion
This old, distant galaxy is the most luminous to have ever been observed. Material is actually being cannibalised from three nearby galaxies, fuelling this quasar and contributing to its record-breaking luminosity.

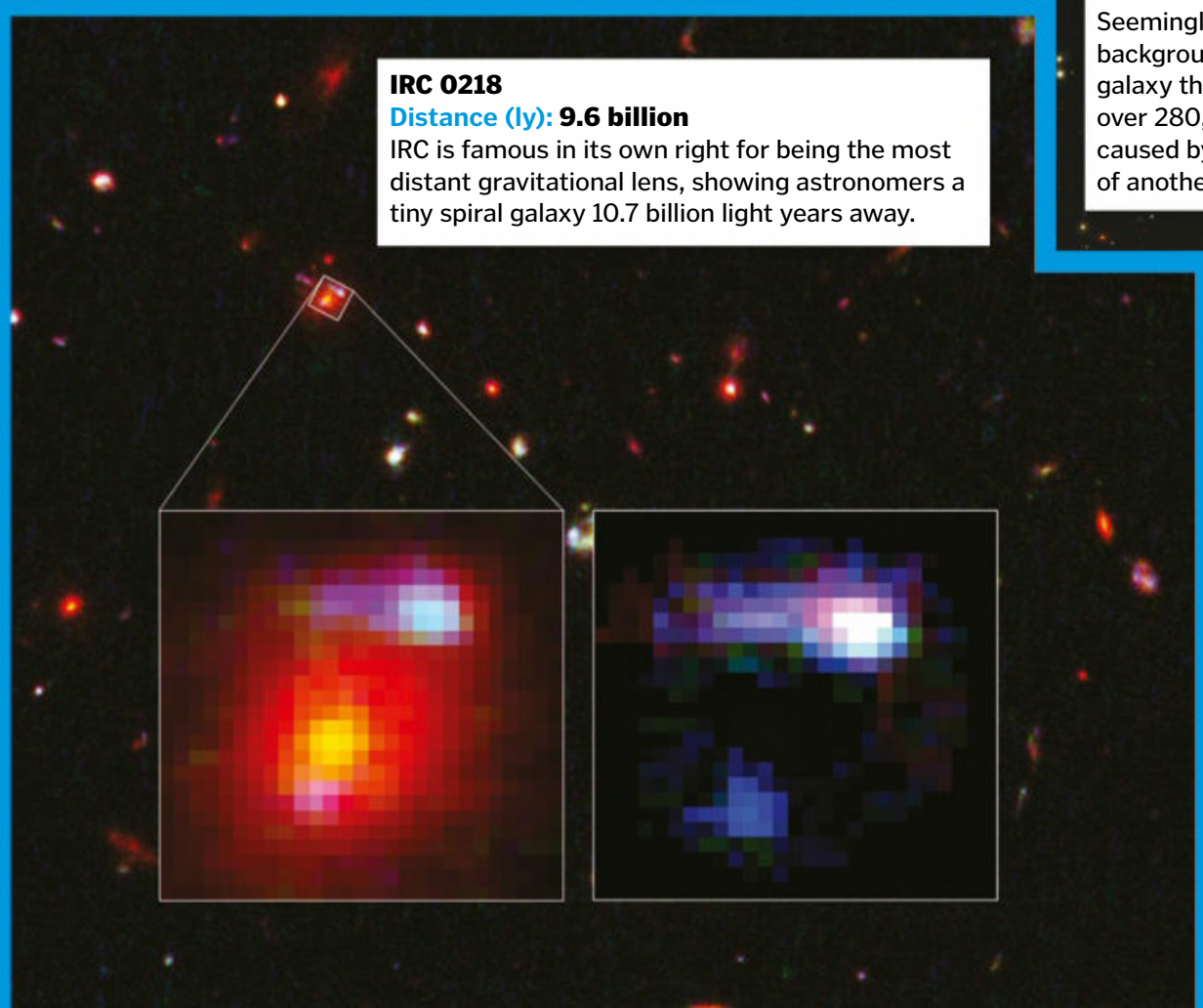


iPTF16geu
Distance (ly): 4.3 billion
Supernova explosions – signifying the end of a star's life – don't emit as much light as a galaxy but are still much brighter than regular stars, making them easier to spot.

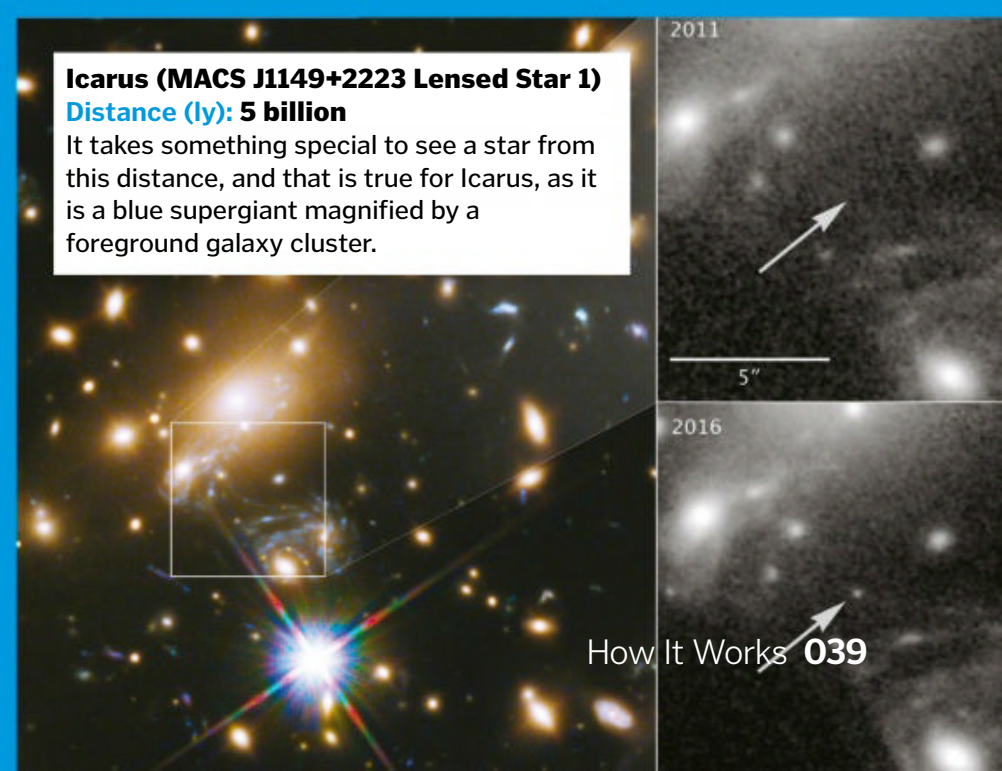


UGC 10214
Distance (ly): 420 million
Seemingly painted on a background of galaxies is another galaxy that has been stretched over 280,000 light years, probably caused by the gravitational effect of another galaxy.

Abell 2218
Distance (ly): 2.1 billion
This is an enormous galaxy cluster with different-coloured Einstein rings around it, corresponding to different background objects and distances.



IRC 0218
Distance (ly): 9.6 billion
IRC is famous in its own right for being the most distant gravitational lens, showing astronomers a tiny spiral galaxy 10.7 billion light years away.



Icarus (MACS J1149+2223 Lensed Star 1)
Distance (ly): 5 billion
It takes something special to see a star from this distance, and that is true for Icarus, as it is a blue supergiant magnified by a foreground galaxy cluster.

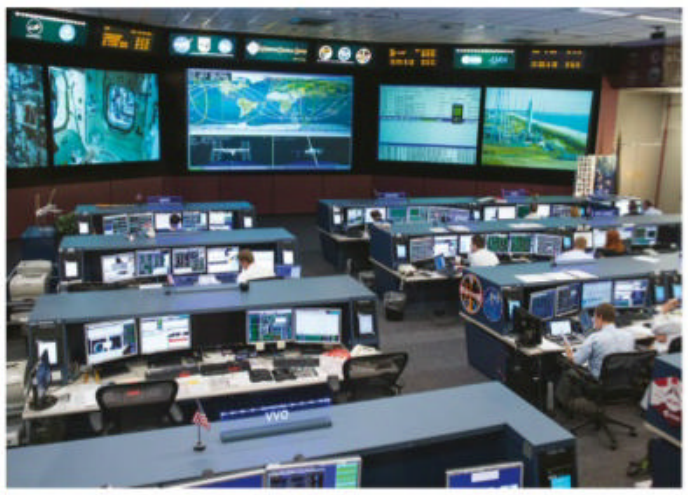
NASA's Mission Control

How the International Space Station and other space missions are kept running smoothly

Mission control centres are locations where space missions are run from. A number of mission control rooms are used around the world to support crewed and uncrewed missions for different space agencies, but perhaps the most famous is NASA's Mission Control Center in Houston, Texas. This is where NASA operates the International Space Station (ISS), and it was also once the home of the Apollo missions to the Moon, and the space shuttles.

Inside this control room, teams work in shifts to keep the ISS running around the clock. The person in charge is the flight controller, who is responsible for keeping the whole mission working. At other stations in the room there are people responsible for talking to the astronauts, checking that the space station is operating properly, and other vital roles.

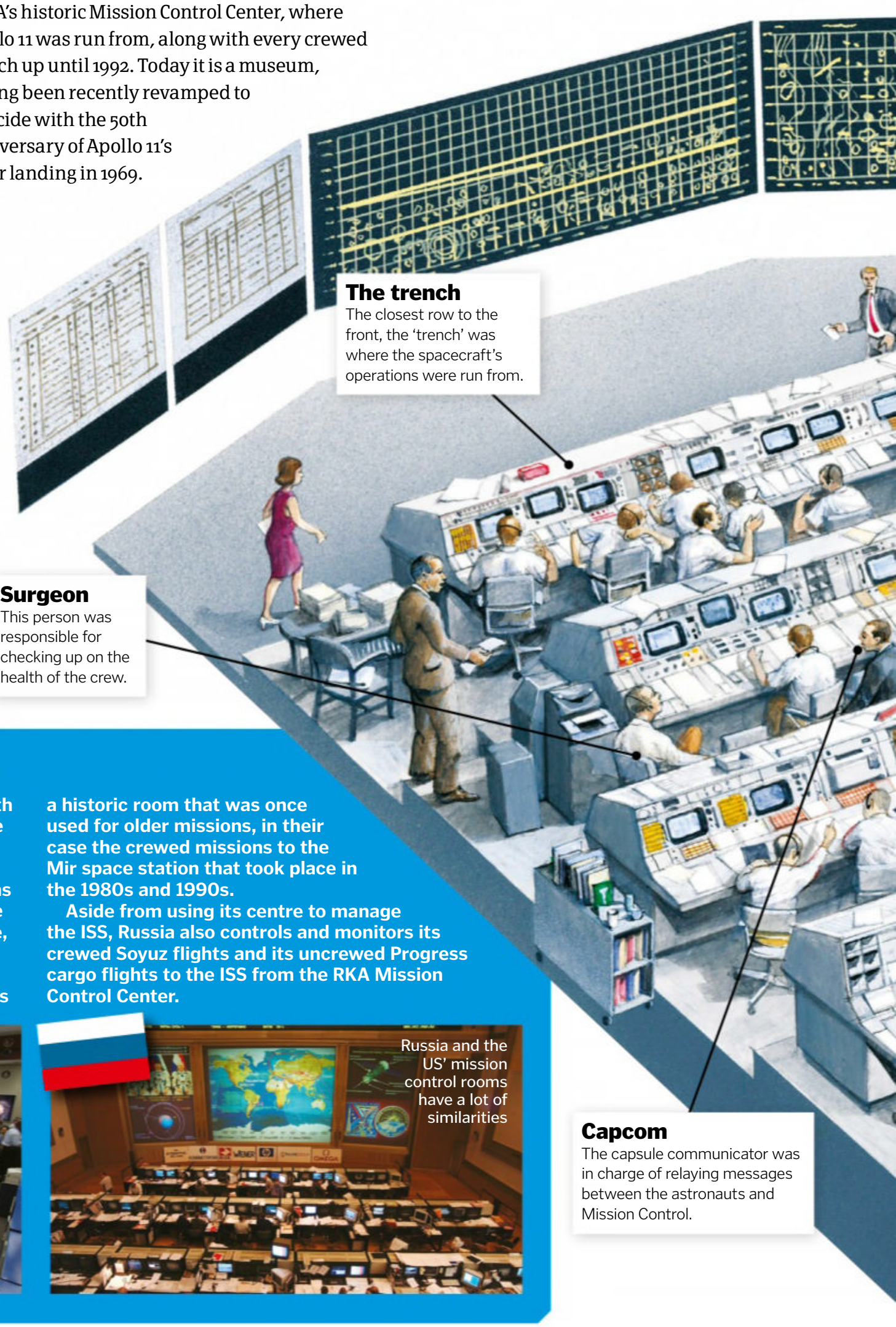
This room is located in the same building as NASA's historic Mission Control Center, where Apollo 11 was run from, along with every crewed launch up until 1992. Today it is a museum, having been recently revamped to coincide with the 50th anniversary of Apollo 11's lunar landing in 1969.



NASA's Mission Control today is used to run the ISS

The heart of the Apollo missions

How this historic room helped achieve one of humanity's greatest moments



The trench
The closest row to the front, the 'trench' was where the spacecraft's operations were run from.

Surgeon
This person was responsible for checking up on the health of the crew.

Capcom
The capsule communicator was in charge of relaying messages between the astronauts and Mission Control.

Russia vs NASA

Russia and NASA's main mission control centres both support their flights to the ISS. Russia's is called the RKA Mission Control Center and is located in Korolyov, just outside Moscow.

Like their counterparts in the US, Russia has teams working 24 hours a day to support their crew on the ISS. With up to six people on the ISS at any one time, split between the US and Russian segments on the station, it's important to have good communication between the two centres. Like NASA, Russia also has a historic room that was once used for older missions, in their case the crewed missions to the Mir space station that took place in the 1980s and 1990s.

Aside from using its centre to manage the ISS, Russia also controls and monitors its crewed Soyuz flights and its uncrewed Progress cargo flights to the ISS from the RKA Mission Control Center.

Russia and the US' mission control rooms have a lot of similarities

Around the world

Many countries and private companies have their own mission control centres across the globe

Flight dynamics officer
The FDO was one of only two people, along with the flight director, who could abort a mission.

Control
This position was responsible for the operation of the lunar lander itself.

Flight activities officer
The FAO was in charge of managing the timeline for the mission, so that everything was on schedule.

Flight director
This person was in charge of running the whole team in Mission Control and on the spacecraft.

NASA HQ
The person in this seat was the point of contact between Mission Control and NASA Headquarters in Washington DC.

Public affairs officer
This seat was saved for the person who relayed what was going on to the public.

Viewing area
Here 74 authorised visitors were allowed to watch what was happening in Mission Control.

An alarming landing

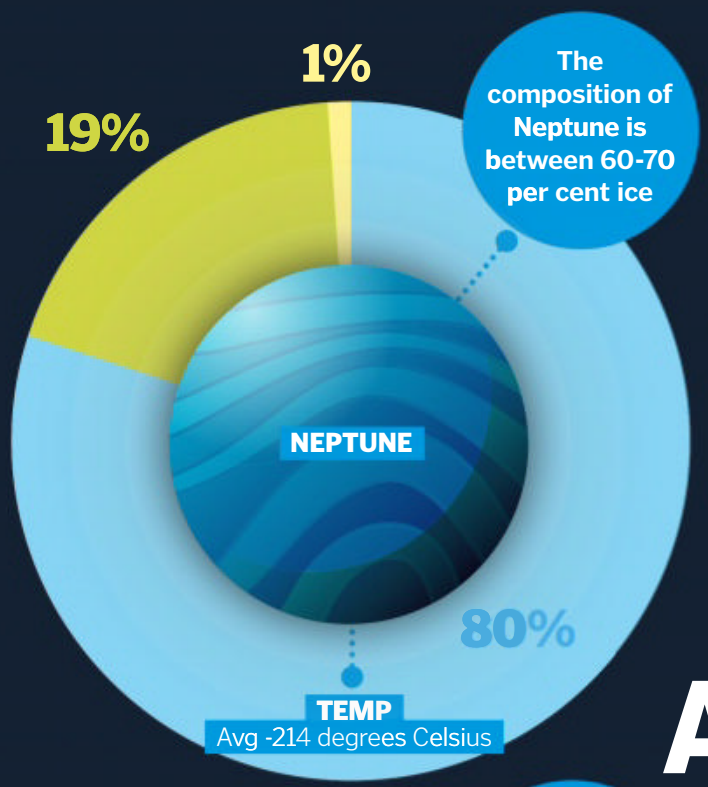
As Apollo 11 came in to land on the Moon on 20 July 1969, a warning light started flashing in the spacecraft. The astronauts had never seen this light before, and when they radioed to Mission Control, people were worried they might have to abort the landing. With just seconds to go before reaching the surface, backroom engineer Jack Garman piped up to say he'd studied the alarms, and it could be ignored. He told his boss, Steve Bales, who signalled they were OK to land. The whole process took 30 seconds, but it was a nail-biting final hurdle just before the first Moon landing.

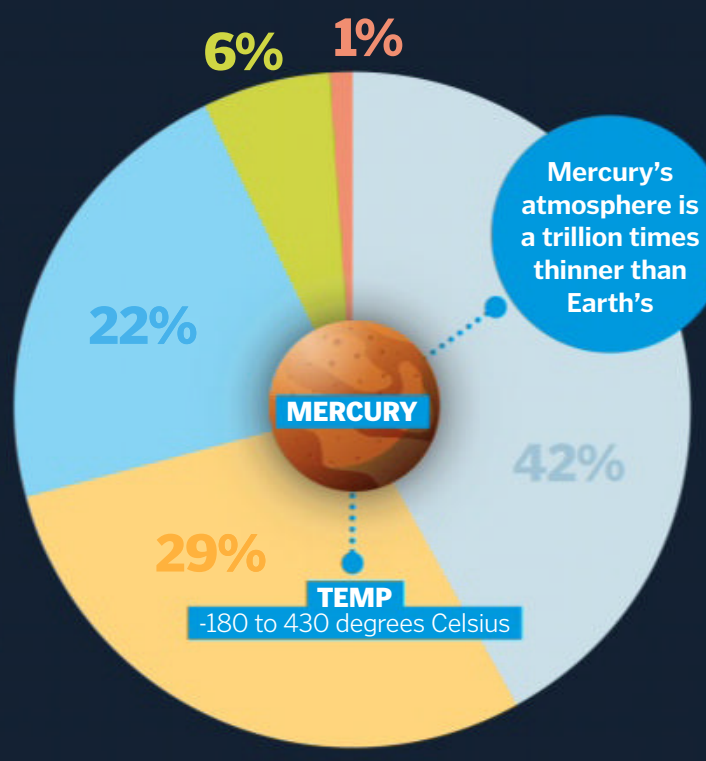
Jack Garman saved the Apollo mission from failure at the final moment

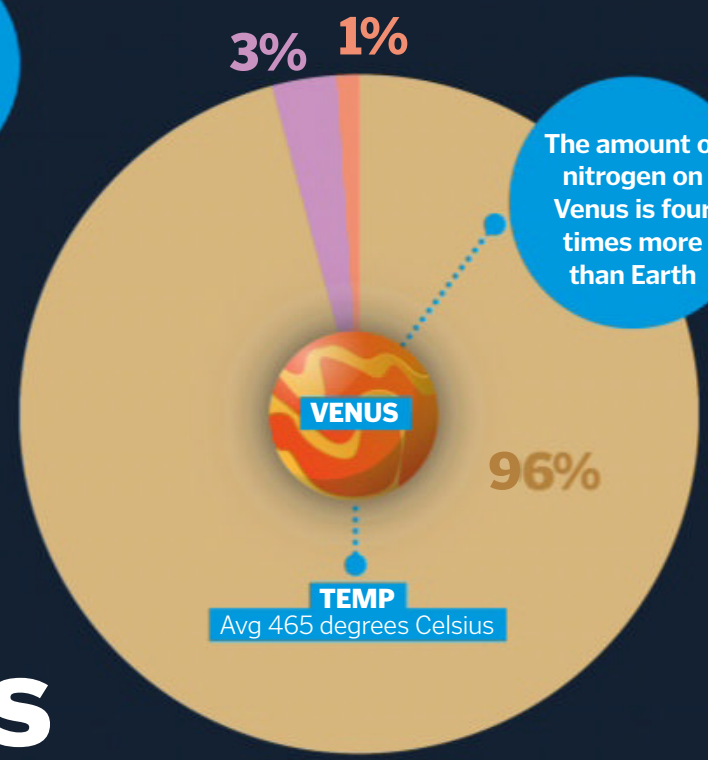
A famous scene of jubilation from Mission Control after Apollo 11 successfully touched down on the Moon

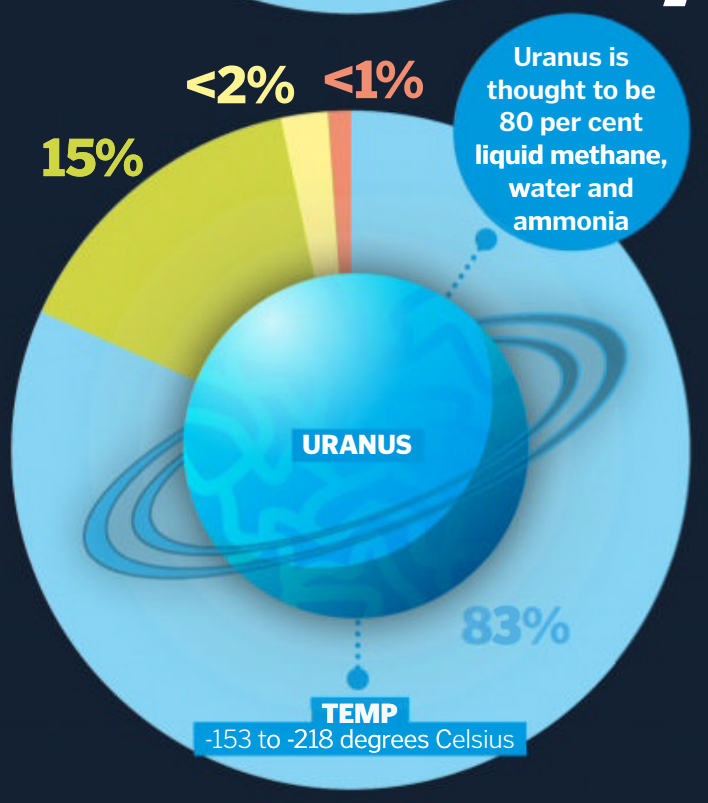
Atmospheres of the eight planets

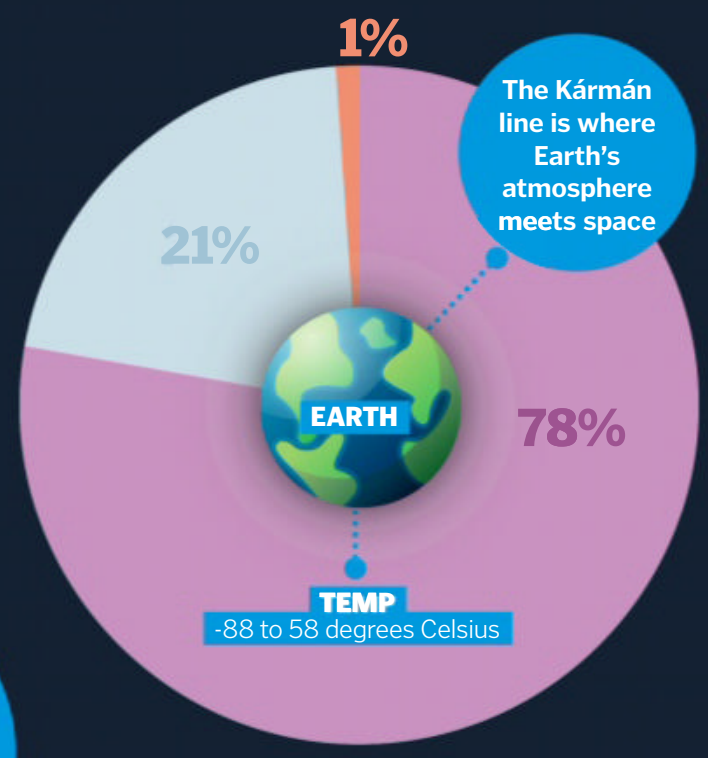
With volatile gases and crushing pressures, some places in the Solar System aren't quite as pleasant as Earth...





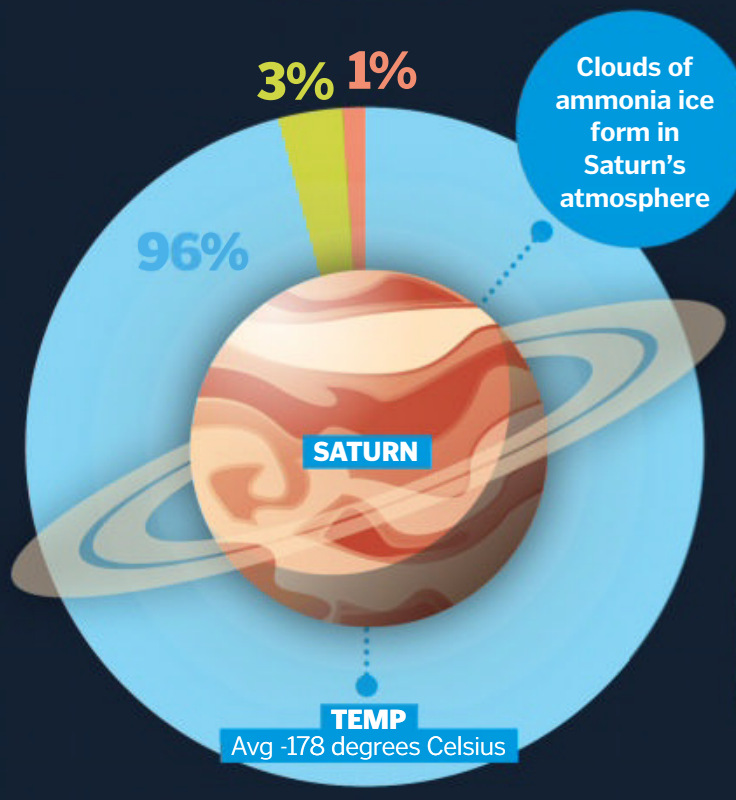


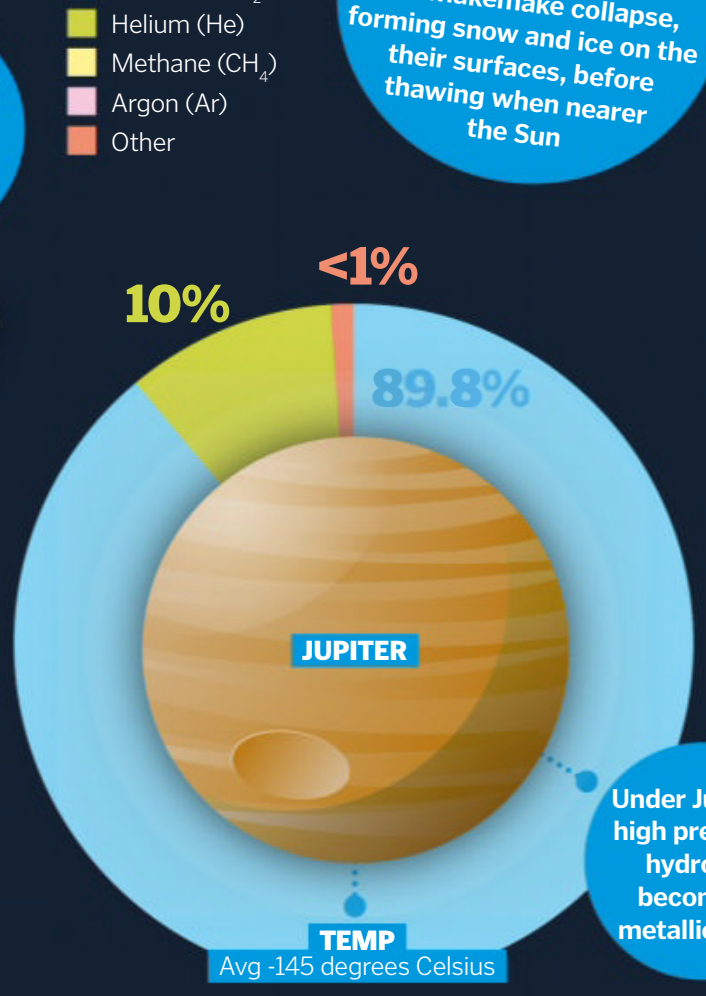


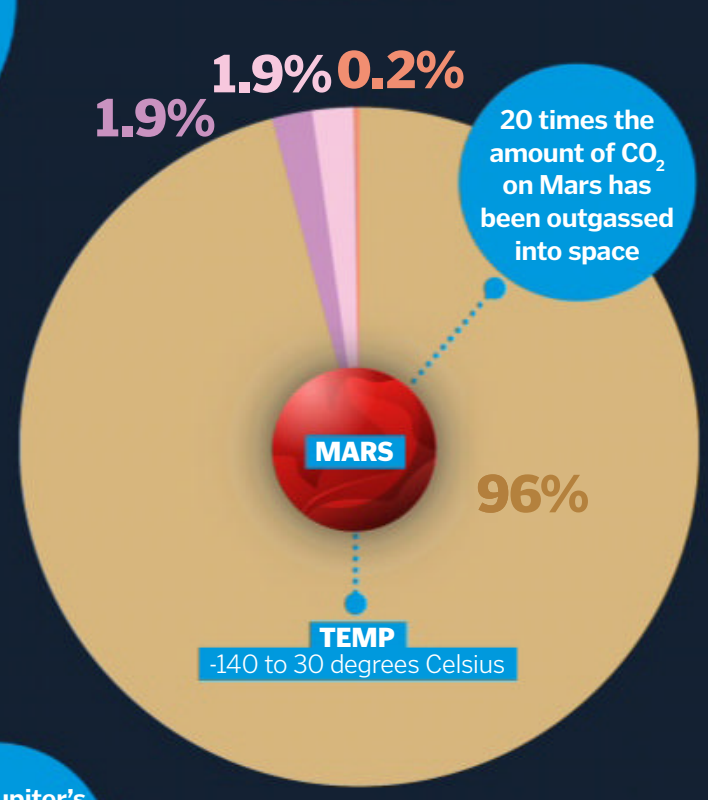


- Nitrogen (N_2)
- Carbon dioxide (CO_2)
- Oxygen (O_2)
- Sodium (Na)
- Hydrogen (H_2)
- Helium (He)
- Methane (CH_4)
- Argon (Ar)
- Other

Due to their distance from the Sun, the atmospheres of dwarf planets such as Eris and Makemake collapse, forming snow and ice on the their surfaces, before thawing when nearer the Sun







WHY DO BIRDS SING?

Discover what motivates the birds of the world to sing and learn the lyrics to their time-honoured tunes

Words by **Amy Grisdale**

Many bird species create music that's so beautiful it has inspired poets, artists and musicians throughout human history. They have made it into our everyday lives and speech, whether you're a night owl or up with the lark. Wherever we are in the world, birds are always there filling our ears with their morning choruses.

Unfortunately, many species of songbird are in decline, even some that are considered common. Numbers of some widespread species have dropped by more than 80 per cent in the last 50 years, like the northern bobwhite. Populations of the UK's songbirds are dwindling despite efforts to increase hedgerows and broadleaf woodlands. Non-native species like grey squirrels, and predatory pets like cats have been blamed for an almost 90 per cent decline in numbers of some birds, such as spotted flycatchers and corn buntings.

Despite these shocking statistics, songbirds can be saved. New areas are being created to allow them room to roost, and existing meadowland and hedgerows are being protected. Many more tunes and verses influenced by nature's musicians are yet to come – hopefully their sublime songs will never be silenced.

Territorial tunes

A songbird will defend its territory with song

While we often associate birds' singing with spring, they also sing in the winter. Generally speaking, this is to defend their territory. Their song warns other birds of their presence and tells them that the area is inhabited. As with mating, the louder the song, the more effective it is at keeping rivals away. Robins can be heard in the winter because they are territorial all year round and sing to ward off rivals. They will use their song and red breast to defend their territory, and can be quite aggressive while doing so.

One reason for hearing birds in the morning is thought to be because females are most fertile earlier in the day, so it is at this time that males will try to keep opponents away. It is also a chance for birds to listen out and find where there are new territories to move into.

"Robins can be heard in the winter because they are territorial all year round and sing to ward off rivals"

Going courting

Birds use melodies to serenade mates

Generally only male birds sing, and often they do so to attract a female during breeding season. This is why we tend to hear them singing from January to July.

The reason a male songbird can often be heard in the morning is believed to be because it shows he has survived the night and is able to find food, which makes him an attractive mate.

Another attractive quality to female birds looking for a partner is singing loudly, as this shows that the male bird has strength and stamina. A male winter wren only weighs 9.4 grams but can sing ten times louder than a crowing rooster, making him highly desirable to females.

Each songbird has a distinctive call that helps the female make her selection. The brown thrasher can sing thousands of melodies, but the house sparrow only has one simple song in its repertoire. The superb lyrebird has the most complicated tune and the Bengalese finch practises for 50 days to perfect its sound. These are all qualities that the female will consider when choosing a new mate.

Birdsong fills the morning air when males begin to lure females at dawn

Singing on the wing

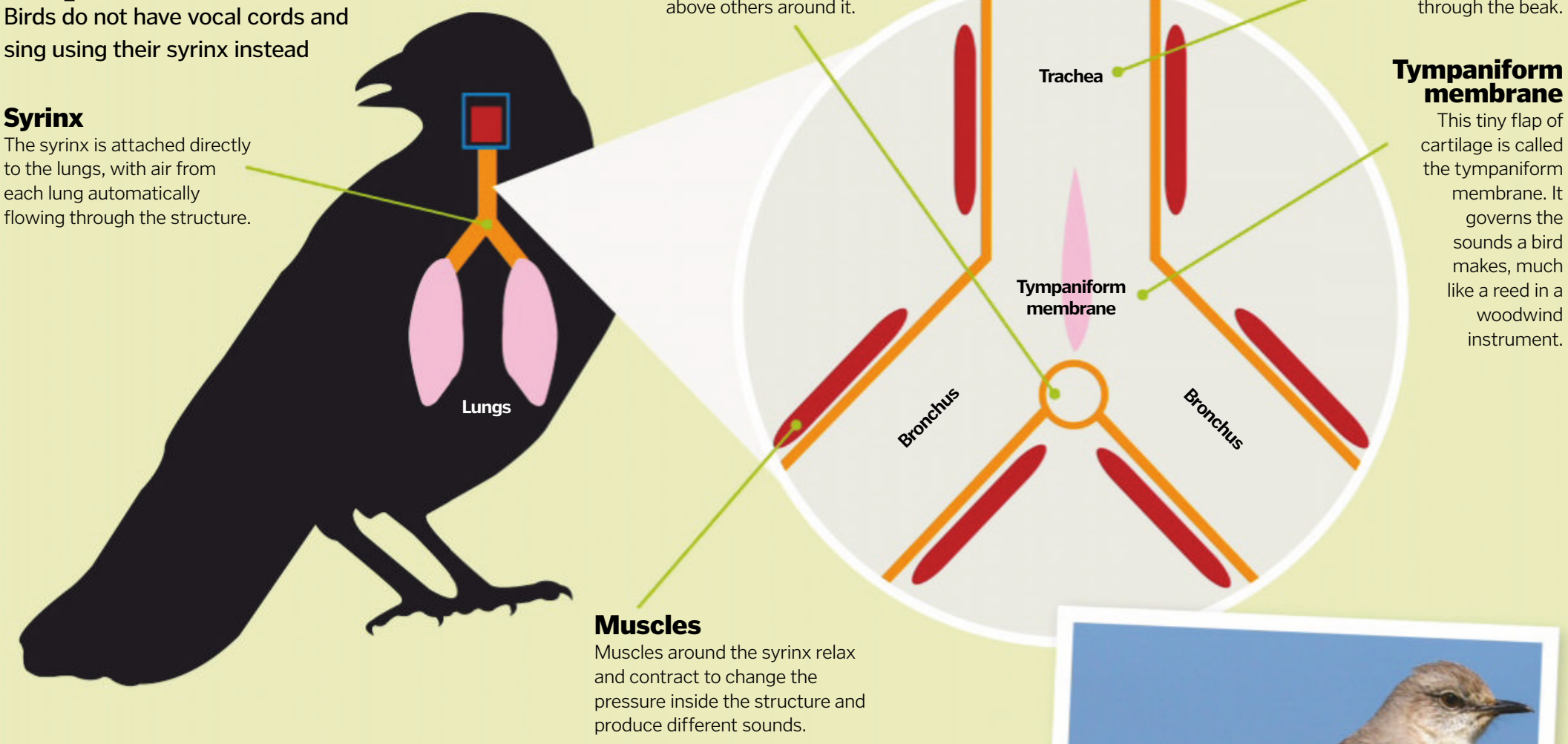
Birdsong can be used during flight

Some birds use their song during flight. They may recruit other birds of the same species to join their colony, like starlings that fly in large flocks. The song flight of the skylark can last up to an hour and is also used to mark their territory. They can fly almost vertically up to 300 metres, soaring for a few minutes before diving down.

Song can also be used to add to an elaborate flight display, like the western sandpiper, which sings while performing acrobatic aerial feats.

Birdsong explained

Birds do not have vocal cords and sing using their syrinx instead



Syrinx
The syrinx is attached directly to the lungs, with air from each lung automatically flowing through the structure.

Air sacs
This small air sac helps a bird increase the volume of its song so it can be heard above others around it.

Trachea
All of the sounds a bird makes are produced at the base of the trachea, or windpipe, before travelling up and out through the beak.

Tympaniform membrane
This tiny flap of cartilage is called the tympaniform membrane. It governs the sounds a bird makes, much like a reed in a woodwind instrument.

Muscles
Muscles around the syrinx relax and contract to change the pressure inside the structure and produce different sounds.

Birdsong battles

Male nightingales impress females with song battles

Research has shown that this little brown bird, famous for its song, will try to win over a female bird by cutting off another male mid-song in a commanding display of aggression. Male nightingales compete for the attention of the female nightingale by trying to out-sing each other from a choice of over 300 songs from their repertoire.

A study published in *Animal Behaviour* in 2006 led by Dr. Hansjoerg Kunc showed that the more often a male nightingale was successful at interrupting another bird's song, the more likely he would be to win over the female. It seems that aggression in male nightingales is a sign of a good mate, as a strong male is one who can defend his territory and his family.

Nightingales sing during the day and in the evening, but they get their name from the fact that unpaired males often sing into the night in order to attract a mate. They are often the only birds to be heard at this time.

Other birds who compete by trying to cut each other off when singing include black-capped chickadees, great tits and also domestic canaries.

The song of the great tit sounds like it is calling "teacher teacher"

Musical mimicry

Birds imitate others to get the girl

Some birds use the art of imitation to attract females during the mating season. If recognising a distinct birdcall is what attracts a female bird, you may wonder how a mockingbird – known for its mimicry – succeeds in love. The northern mockingbird mimics other birds day and night; it has 200 different calls and can imitate over a dozen different birds. It attracts females by adding to its own original sound in order to be even more impressive.

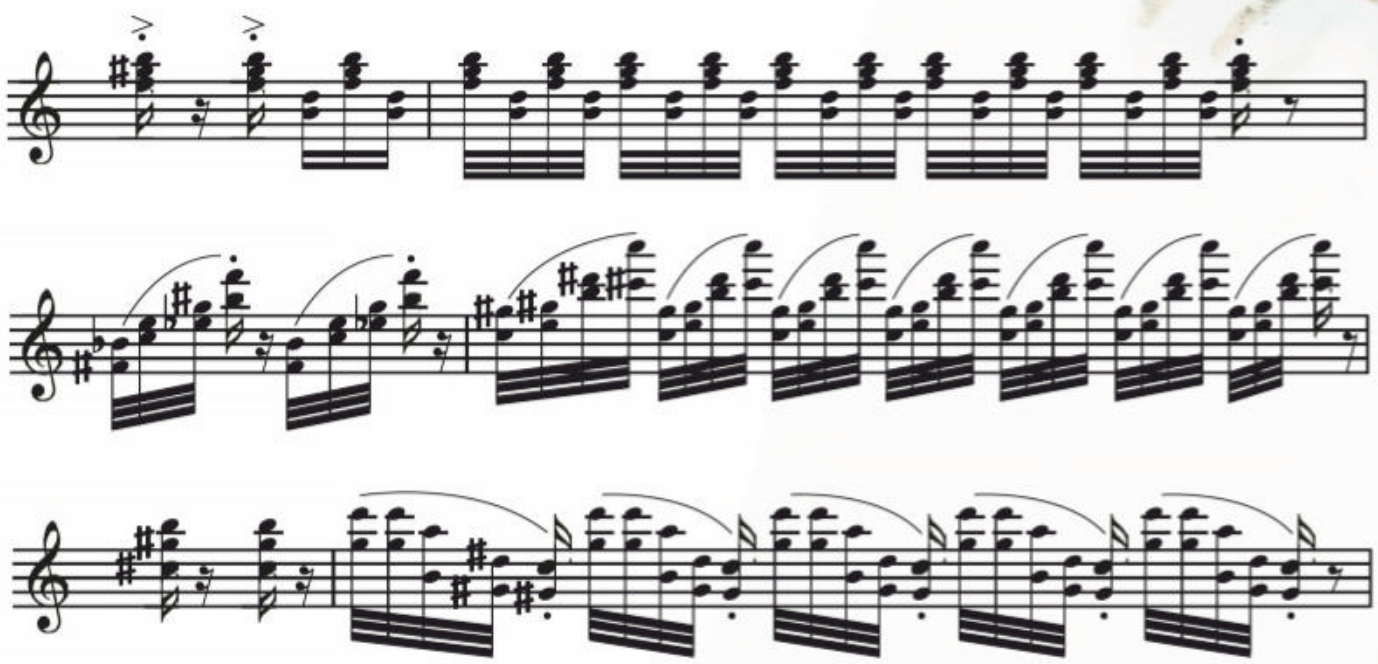
The superb lyrebird is such a good impersonator that even the bird it is mimicking occasionally gets confused. The satin bowerbird has also been found to attract mates through the variety of sounds it can imitate.

Songs of the cardinal

These stunning red birds sing extremely impressive songs, with both males and females showing musical abilities

Adorned in brilliant red, these are some of the most iconic songbirds found in North America. Female cardinals are brown with a red crest and beak, and while they don't share the male's vibrant plumage, they do share an incredible vocal ability. The song of a cardinal is like a sound effect from a science fiction film. They produce sequences of whistled syllables that sound like futuristic laser beams. Each cardinal song can contain a single syllable type or up to three, and it really has to be heard to be believed.

Cardinals are easy to recognise with their distinctive crest. They are about 21 centimetres long and feed on seeds, fruit and insects. Offering sunflower seeds is a good way of attracting them to your garden if you want to hear a sample song, and they are around all year long.



Sheet music for a cardinal's song. The different syllable types come out in different cardinal songs

"The song of a cardinal is like a sound effect from a science fiction film"

Beatboxing bird

Java sparrows click their beaks in time to their song, which sounds a bit like beatboxing

Java sparrows produce non-vocal sounds at the same time as singing. Just like a human beatboxer, male birds click their beaks in time with their tunes to create a multi-layered sound. Research into this phenomenon is ongoing, but so far researchers think this ability is passed down from father to son. Keeping a beat may make the sparrows more attractive to females, helping males find a life partner. Monogamous animals often develop complex communication, so these songs could be a method of reinforcing bonds between birds.

"Just like a human beatboxer, male birds click their beaks in time with their tunes to create a multi-layered sound"

Songbirds of the world

How to identify some of the birds that learned to sing long before the dawn of humankind, and to attract them into your garden

Blue tit

A gardener's best friend, they eat insects like aphids that are harmful to flowers

Size: 12 centimetres long
Appearance: Blue-green back, white cheeks, blue crown and yellow breast
Diet: Insects, seeds and nuts
Song: One high note followed by several repeated lower notes
When to see them: All year round
Where they live: Throughout Europe
How to attract them: Put out peanuts, sunflower hearts and mealworms

Weaver

Black-headed weavers build intricate spherical nests, often with multiple entrances

Size: 15 centimetres long
Appearance: Black head, bright orange and yellow breast
Diet: Seeds and insects
Song: Repetitive, creaking trills
When to see them: April to August
Where they live: West and central Africa
How to attract them: Provide grasses for nest building and maintenance

Nuthatch

They're often seen diving between the branches of trees head first

Size: 11 centimetres long
Appearance: Blue-grey back, rust-coloured breast and a black stripe across each eye
Diet: Insects, nuts and seeds
Song: Two to five repeated notes
When to see them: All year round
Where they live: North America
How to attract them: Put out hazelnuts

Gouldian finch

This rainbow-feathered Aussie has several different colour morphs. Only 25 per cent has a red face

Size: 14 centimetres long
Appearance: Extremely colourful, with a triangular beak. Head can be red, black or yellow.
Diet: Ripening grass seeds, insects
Song: Quiet whistling
When to see them: November to March
Where they live: Northern Australia
How to attract them: Establish a tree hollow for them to roost in

House martin

Their nests take over a week to build with over 1,000 beak-sized pellets of mud

Size: 12 centimetres long
Appearance: Glossy blue-black with a forked tail
Diet: Insects
Song: High-pitched twittering
When to see them: April to October
Where they live: Across Europe over summer
How to attract them: Provide a muddy pool to help with nest building

Wallcreeper

These high-fliers spend summers at altitudes of 2,000 metres or more

Size: 15 centimetres long
Appearance: Grey head with red, black and white wings
Diet: Insects, also occasionally seeds and nuts
Song: One high note followed by several repeated lower notes
When to see them: All year round
Where they live: Mountains of Eurasia
How to attract them: Provide some peanuts and sunflower hearts

Robin

These feisty red-breasted birds are extremely territorial and can get aggressive, especially with other robins

Size: 14 centimetres long
Appearance: Brown back with a bright orange-red breast
Diet: Worms, seeds, fruits and insects
Song: High pitched and musical
When to see them: All year round
Where they live: Throughout western Europe
How to attract them: Provide mealworms

HOW DESERTS FORM

Discover the world's largest deserts and why these dry (but not barren) areas exist

Words by **Scott Dutfield**

Across vast expanses of thirsty land, silence is met with the occasional caw of a passing vulture or the howl of the wind. Our imaginations often conjure this typical scene when we think of our planet's deserts. But deserts are not defined by the amount of sand they hold or how sun-baked their landscapes are. A 'desert' is classified as a region that receives little to no precipitation – typically less than 25 centimetres annually. Some of the world's largest deserts are indeed hot stretches of sand, such as the Sahara Desert, but in fact the largest of them all is quite the opposite.

Spanning over 14 million square kilometres and the coldest place on Earth, the Antarctic wins the title of the world's largest desert. Due to cold air's poor ability to hold water vapour, the icy expanse doesn't receive much precipitation.

What helps keep Antarctica a frozen wasteland is its snowy white appearance. Known as the albedo effect, the Sun's warming rays are naturally reflected by light surfaces and sent back towards space. With such a large surface area, the Antarctic, as well as its Northern cousin, the Arctic (the world's second-largest desert), avoid being melted by the Sun's heat, and so do not release water.

It is not the same for some of the other big deserts. Located around 30 degrees from the Earth's equator, the subtropical deserts have been laid to waste, deprived of regular rainfall and dehydrated by the Sun over thousands or even millions of years. It's a process known as aridification, and the Sahara Desert is the largest subtropical desert to be stripped of lush vegetation as a result of this process, around 7 million years ago. One theory suggests that during the breakup of the world's supercontinents, which started around 250 million years ago, the African and Eurasian plates collided. As a result, the Alps were slowly formed, while a sea known as Tethys was lost. This body of water had played a vital role as a watering can for the surrounding land, including what is now northern Africa. The sea shrunk as the two plates collided, the precipitation gradually diminished and the Sahara's dry spell began, lasting to the modern-day. High winds and little rainfall resulted in the vast expanse of desert we see today.

Deserts may appear to be lifeless expanses but are actually home to highly adapted survivalist species. Mammals such as the fennec fox, found in the Sahara, have evolved to take advantage of the desert's cold nights. To avoid the Sun's blasting daytime heat, these mammals are nocturnal hunters, feasting on invertebrates, small rodents, birds and their eggs.

Water is a hot commodity among the scorching sands, and some species have developed clever ways to find water. Some beetles in the Namib Desert utilise hydrophilic points on their back to collect water vapour from fog. As droplets form on the beetle, hydrophobic wax directs the water towards the beetle's mouth.

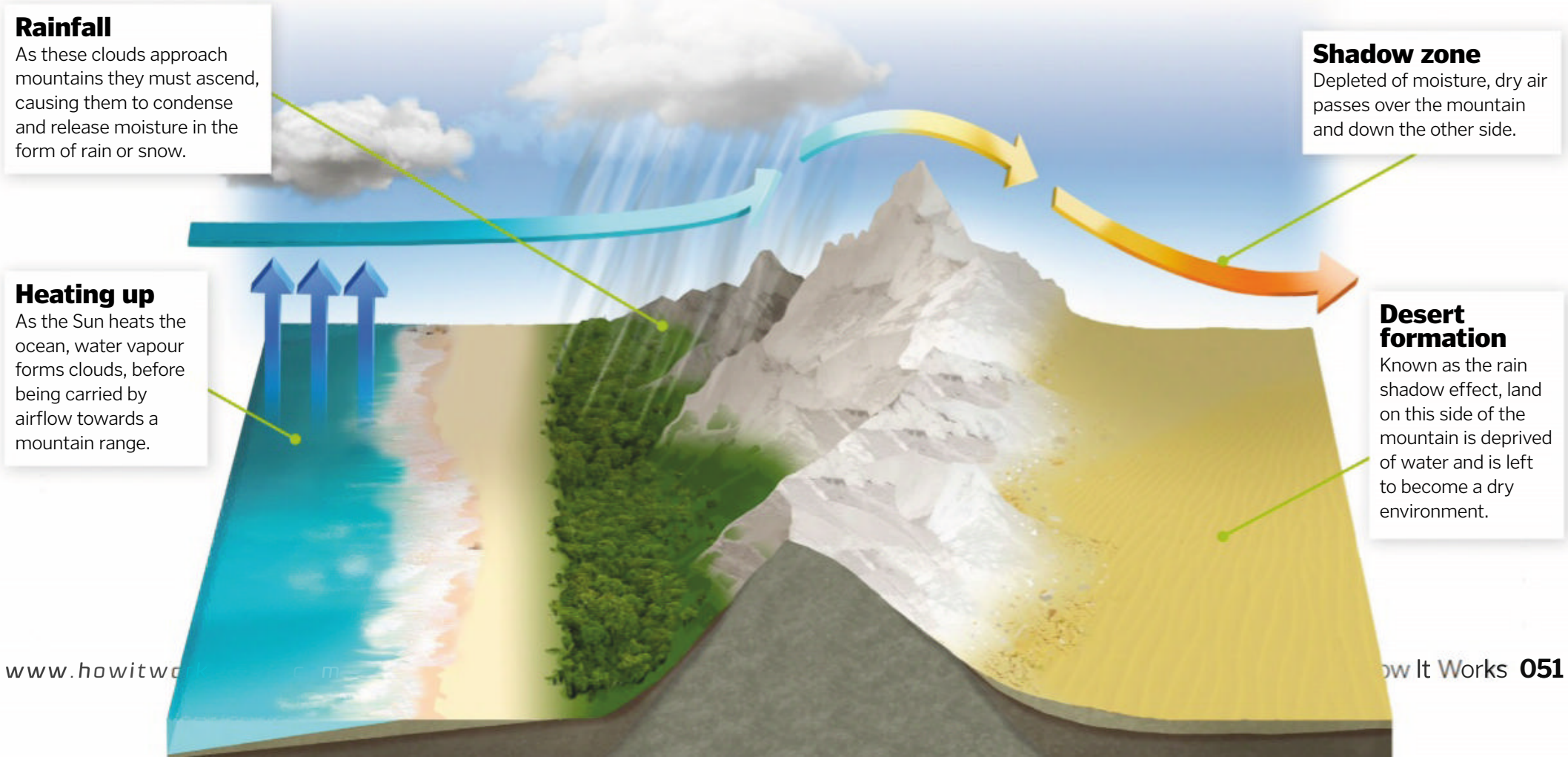
Lagoons among the dunes

Though not technically classed as a desert, the Lençóis Maranhenses National Park in Brazil resembles a desert scene that collects and stores rainwater. A popular tourist destination, this park spans 1,550 square kilometres, and for six months of the year it hosts brilliant blue and green pools. This juxtaposition of environments is the result of two factors. Firstly, the underlying bedrock is so dense and non-porous that rainwater is unable to seep into the ground, instead forming lagoons. The perfectly carved dunes are thanks to the high-speed winds of the arid environment: in a process known as saltation, larger grains of sand are lifted by powerful winds and dropped into a deep symmetrical U-shaped dune, called a parabola.

Six months' worth of rainfall collects between the national park's dunes to form lagoons

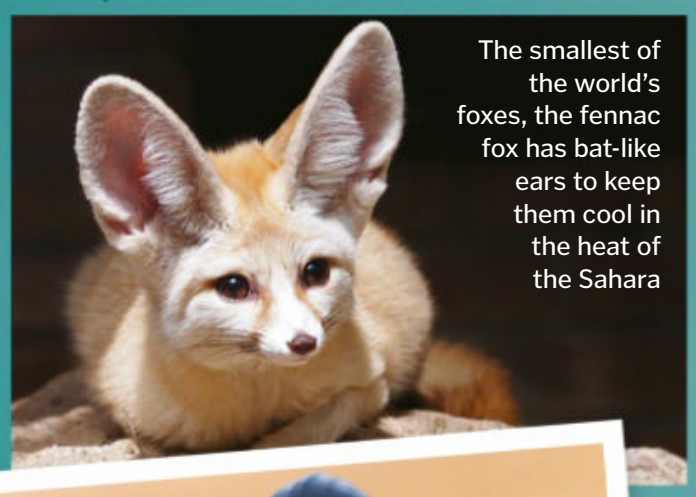
In the shadows of giants

Deserts form as a result of many contributing factors, whether it's in the deep freeze of the Arctic or because it simply misses the regular pathway of rainfall. However, living in the shadow of a mountain has forged some of the world's largest colder deserts, such as the Great Basin Desert in the US or Asia's Gobi Desert. Though still distinguished by a sandy surface, these are robbed of precipitation thanks to their towering neighbours.



The world's ten largest deserts

These dry landscapes can be found scattered across the globe



The smallest of the world's foxes, the fennac fox has bat-like ears to keep them cool in the heat of the Sahara

Namib Desert beetles have evolved a filtration system on their back to collect water from passing fog

© Alamy

2 Arctic

Type: Polar
Size: 14 million square kilometres
Average temp: -10 to -34 degrees Celsius
Annual rainfall: 15 to 25 centimetres

9 Great Basin

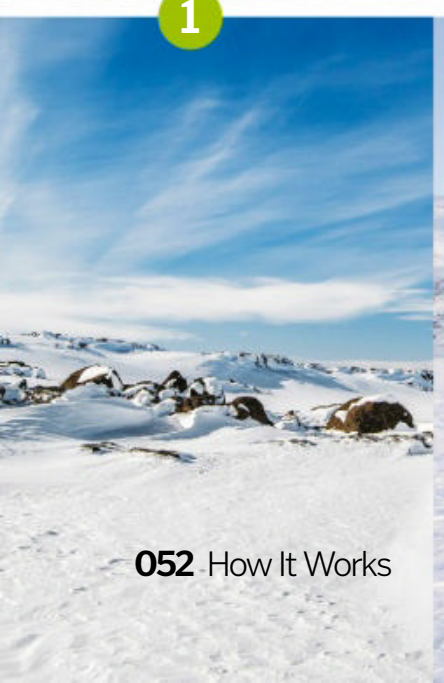
Type: High desert
Size: 492,000 square kilometres
Average temp: -8 to 30 degrees Celsius
Annual rainfall: 15 to 30 centimetres

7 Patagonian

Type: Cold desert
Size: 673,000 square kilometres
Average temp: 4 to 20 degrees Celsius
Annual rainfall: 12 to 20 centimetres

1 Antarctic

Type: Polar
Size: 14.24 million square kilometres
Average temp: -10 to -60 degrees Celsius
Annual snowfall: 5 centimetres



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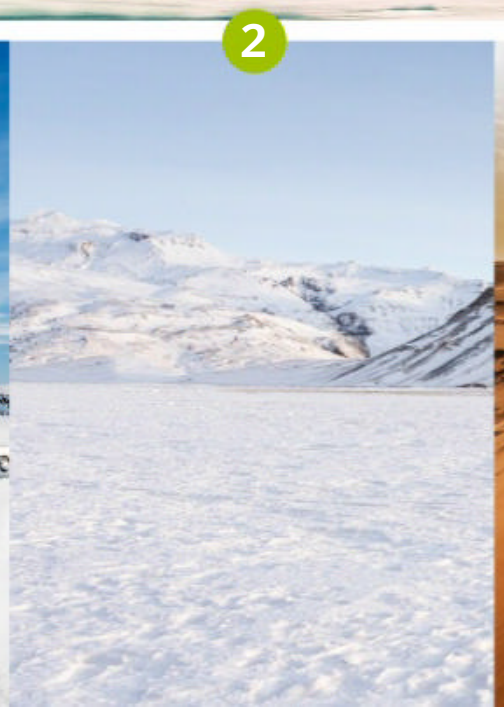

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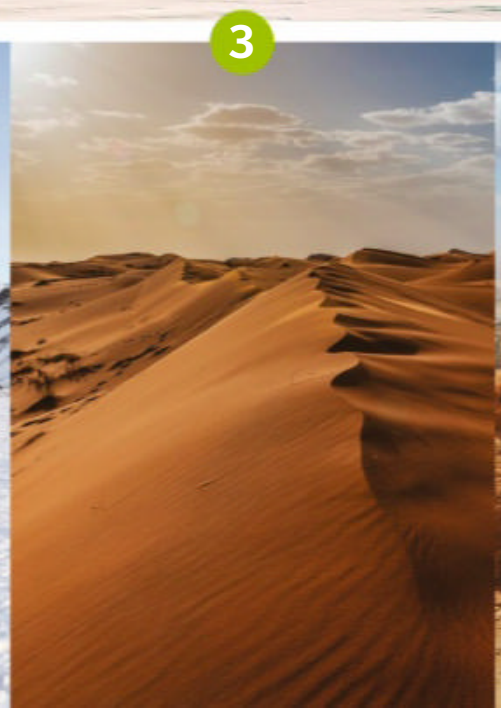

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4

5

8 Syrian
Type: Subtropical
Size: 500,000 square kilometres
Average temp: 4 to 31 degrees Celsius
Annual rainfall: <12.5 centimetres

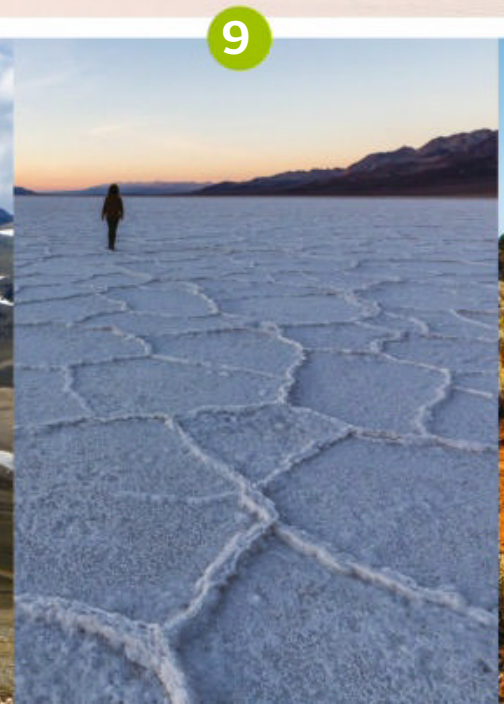
4 Arabian
Type: Subtropical
Size: 2.3 million square kilometres
Average temp: 6 to 50 degrees Celsius
Annual rainfall: <10 centimetres

5 Gobi
Type: Cold desert
Size: 1.3 million square kilometres
Average temp: -40 to 45 degrees Celsius
Annual rainfall: 5 to 20 centimetres

3 Sahara
Type: Subtropical
Size: 9 million square kilometres
Average temp: 30 to 50 degrees Celsius
Annual rainfall: <2.5 centimetres

6 Kalahari
Type: Subtropical
Size: 930,000 square kilometres
Average temp: -12 to 46 degrees Celsius
Annual rainfall: 12 to 25 centimetres

10 Great Victoria
Type: Subtropical
Size: 420,000 square kilometres
Average temp: 20 to 40 degrees Celsius
Annual rainfall: 15 to 25 centimetres



Explore London's super-sewer

Discover the tunnel being built deep beneath the Thames River and how it's going to prevent poo from contaminating the water

Words by **Scott Dutfield**

In the mid 1800s, London's Victorian sewer system was built to combat the growing outbreaks of cholera and typhoid fever that were killing thousands of Londoners. It was designed by chief engineer Joseph Bazalgette, used around 318 million bricks and spanned the entire city.

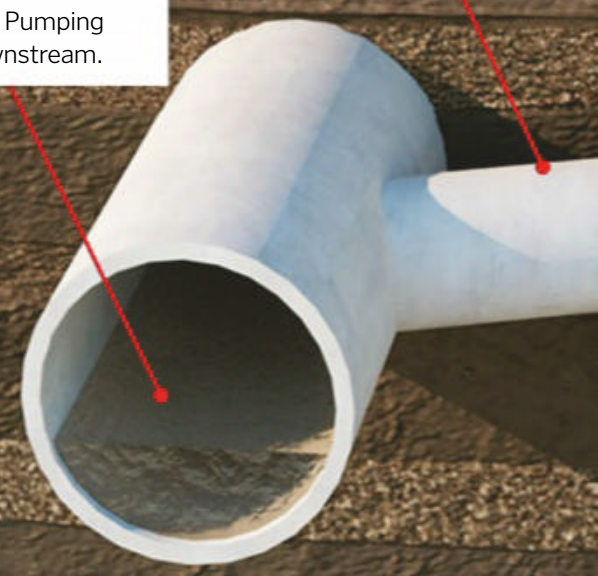
Although the Bazalgette sewer system has served the residents of London well over the past 150 years, it hasn't been without issues. Originally built to support the waste of 4 million people, the capital city is now home to over 8 million people and rising, putting pressure on the city's sewers. Currently the sewers are contending with 1.25 million tonnes of human waste each day.

As a fail-safe to prevent sewage from spilling onto the streets of London, the current network of pipes is connected to several overspill pipes that deposit waste into the water of the Thames. As London's population continues to grow, millions of tons of waste contaminate the river's water.

It is this overspill design that has prompted Tideway, an engineering company, to create the Thames Tideway Tunnel. As an improved

4. Sewer connections
As sewage begins to fill the shaft, it will feed via connecting pipes to the central Thames tunnel.

5. To the pumps
Collected sewage will travel beneath the Thames until it reaches Abbey Mills Pumping Station downstream.



Cleaning up the Thames

How the new Thames Tideway Tunnel prevents overflow from entering the river

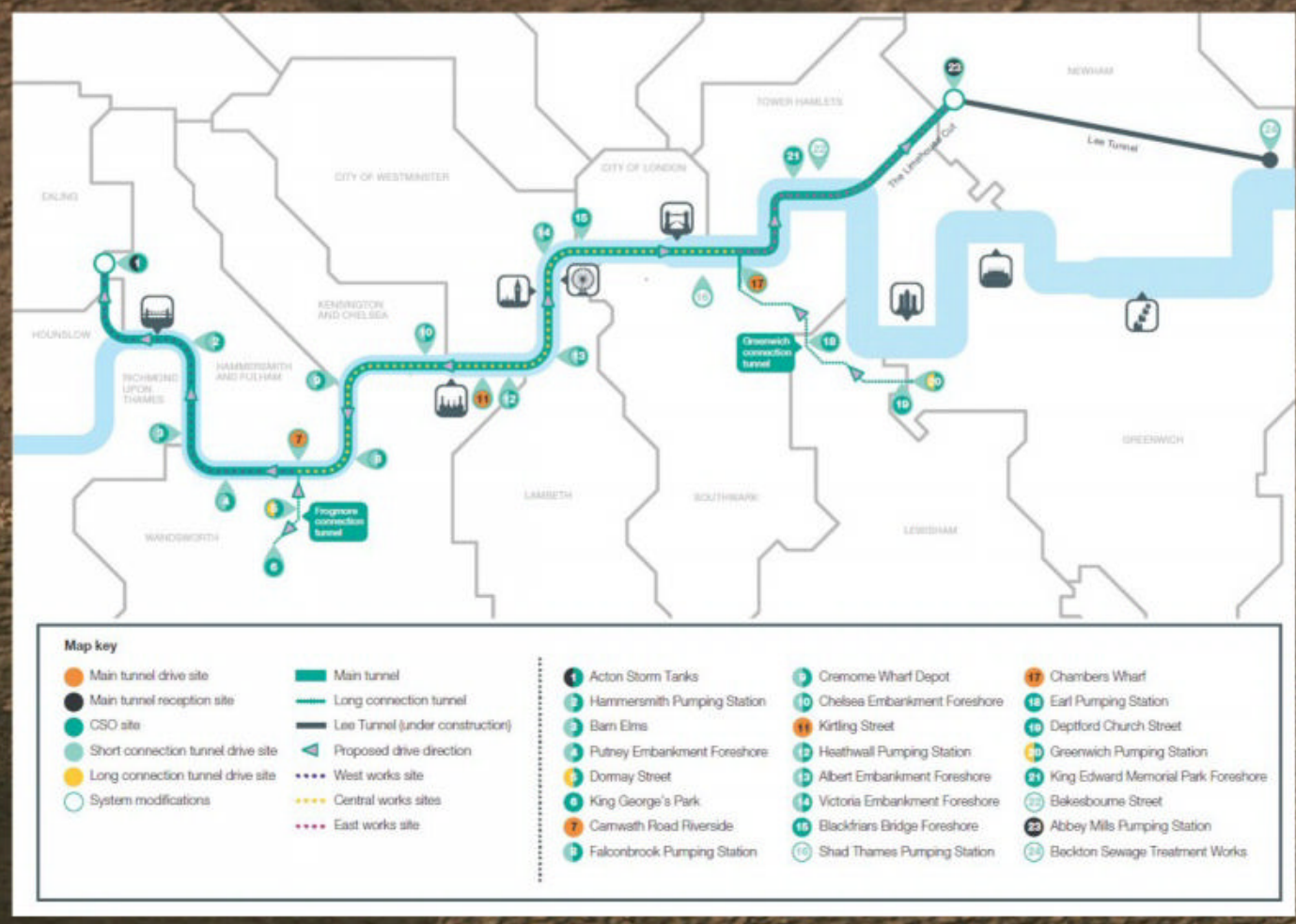
1. Current sewer system
London's current network of pipes deliver untreated sewage to treatment centres around the city.

2. Overflow
In the event of heavy rainfall and sewage overflow, the sewage will spill into newly constructed shafts rather than flow into the Thames.

3. Deep shafts
Sewage will travel down and begin to fill deep shafts at various locations along the Thames.

Subterranean super-sewer

The new tunnel's route takes it from one side of London to the other



A tunnel boring machine is lifted and lowered by a gantry down a shaft

Giant Thames worm

Officially known as a tunnel boring machine (TBM), this mammoth vehicle can cut through bedrock, clearing the way for the new super-sewer under the Thames

Propulsion
The TBM moves with the help of hydraulic rams that push against the newly placed tunnel ring, moving it forward.

Cutter head
Made of steel, this circular, eight-metre mouth of earth-cutting teeth rotates, breaking down soil and rock to form the tunnel.

addition to the Victorian sewers, the new super-sewer is a prime example of engineering precision.

Beginning at Acton Storm Tanks in Ealing, the 25 kilometre-long tunnel will burrow beneath and follow the Thames until reaching Abbey Mills Pumping Station in Newham, London. Sewage collected throughout the tunnel will be sent down the Lee Tunnel, reaching its final destination at the Beckton Sewage Treatment Works.

In order to shape the Thames Tideway Tunnel, massive machinery has been brought in to carve into the rock deep below the river. Known as a tunnel boring machine (TBM), this burrowing behemoth pushes its way through bedrock, shaping the tunnel as it goes. What lies in the wake of the TBM's tunnelling force is tons of displaced rubble. Continually feeding through the belly of the metal beast, excavated material or slurry is carried on conveyor belts back to the surface.

Construction of the tunnel will create 4 million tons of rock and rubble that will need to be removed. Tideway is utilising the Thames to transport the material to landfill sites, via barges that can carry the equivalent to 50 heavy goods lorries. The rubble will then be used to cap off landfill sites, which will then be turned into nature reserves.

48 hours
The time taken to empty the tunnel when full

7.2 metres
The width of the tunnel

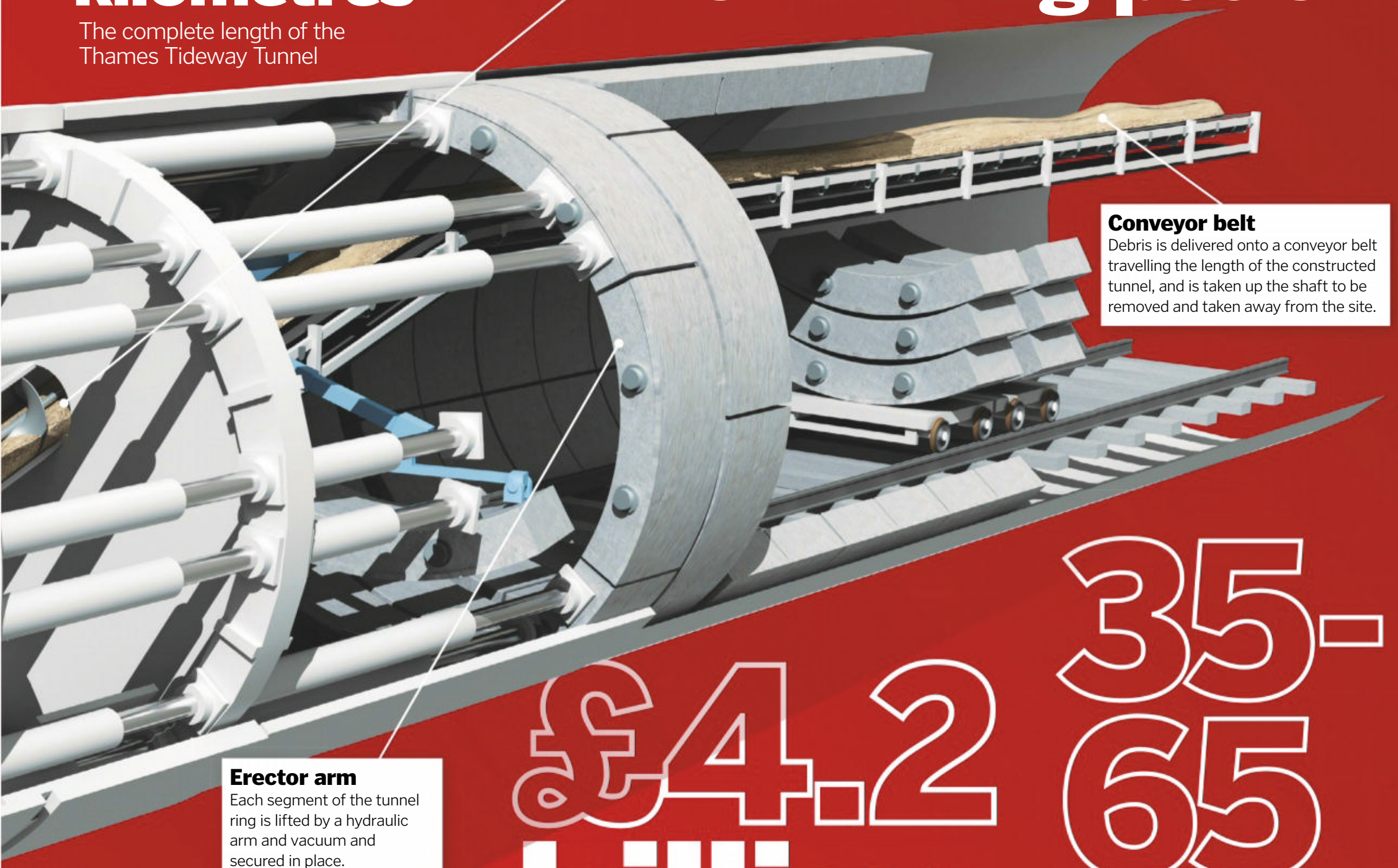
25 kilometres

The complete length of the Thames Tideway Tunnel

600 Olympic-sized swimming pools

Thames Tideway Tunnel's storage capacity is equivalent to

Screw conveyor
Broken-down rock and sediment travels up the 18-metre screw conveyor and is deposited on a conveyor belt.



Conveyor belt
Debris is delivered onto a conveyor belt travelling the length of the constructed tunnel, and is taken up the shaft to be removed and taken away from the site.

Erector arm
Each segment of the tunnel ring is lifted by a hydraulic arm and vacuum and secured in place.

£4.2 billion

Estimated cost to construct the new tunnel

35-65 metres

The depth below the ground the Thames tunnel will run

Constructing London's sewer system

1848
The Metropolitan Commission of Sewers is established to find a solution to London's serious sewage problem.

1858
Following a heatwave that results in the city's famous 'Great Stink', parliament approves the construction of a new London sewer system.

1859
Work begins on a new centralised sewer system, designed by the engineer Joseph Bazalgette.

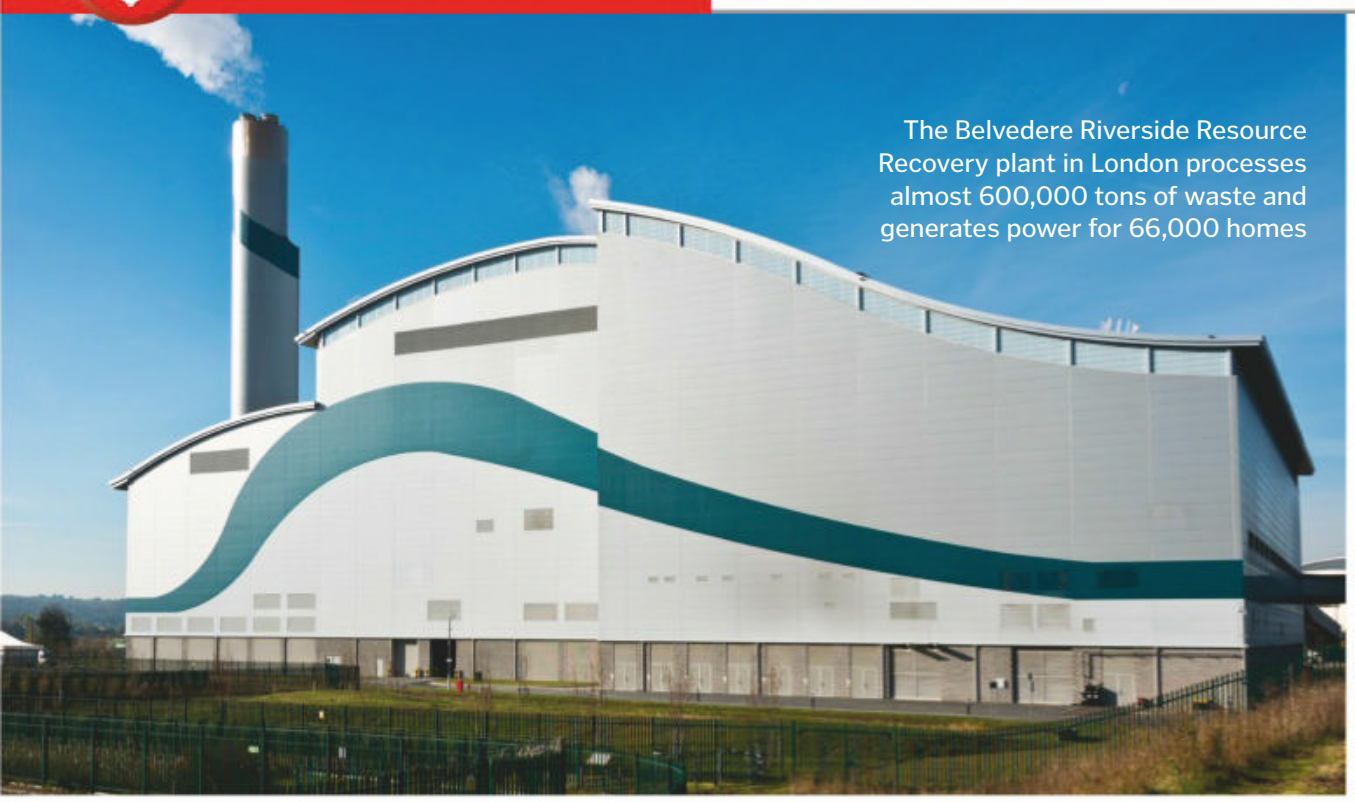
1865
The first phase of Bazalgette sewer system is opened, comprising of 1,770 kilometres of street sewers and around 130 kilometres of underground main brick sewers.

2014
Plans are approved to construct the Thames Tideway Tunnel.

2016
Preliminary work begins to facilitate the tunnel's construction.

2018
The construction of the tunnel begins at Hammersmith Pumping Station.

2024
The target deadline for the completion of the Thames Tideway Tunnel.



The Belvedere Riverside Resource Recovery plant in London processes almost 600,000 tons of waste and generates power for 66,000 homes

Flames roar to over 1,000 degrees Celsius inside a household waste incinerator at an energy recovery unit in France

What's inside a waste incinerator?

These hulking machines burn hot enough to melt metal and send rubbish up in smoke

The UK alone produces approximately 220 million tons of waste annually, a figure that contributes to a global yearly total that hit 1.3 billion tons in 2017. Experts have predicted that this number could reach 2.2 billion by the year 2025 as urbanisation continues to increase. All of this waste has to be collected and handled safely, and one method that is commonly used is incineration.

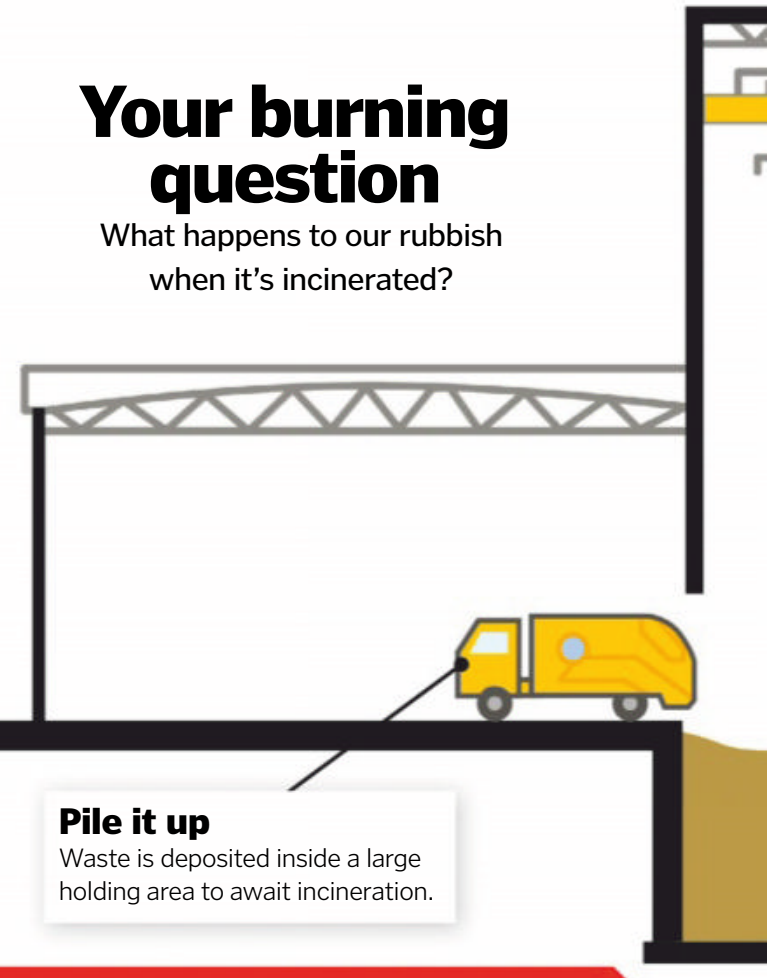
Running at around 750 degrees Celsius, incinerators come in a variety of designs (including those fitted with a rotary kiln), but they all share the same purpose – to safely destroy waste and treat the by-products of this process in order to mitigate the chances of potentially hazardous materials being released into the atmosphere.

This is achieved by first burning the municipal materials collected and then inspecting the ash produced as a result. This ash comes in two forms: fly (or flue) and bottom ash. The latter is the least dangerous as it clings to the searing sides of the incinerator. This type of ash is inspected with a magnet to retrieve any valuable metals for recycling. However, the finer variety of fly ash can be unsafe to expel from chimneys, as it often contains gaseous traces of heavy metals such as lead and mercury. Fly ash is therefore passed through a scrubbing device to treat and remove any harmful substances from the exhaust before it is released.

There are currently 44 waste incinerators in operation in the UK, and many environmentalists are concerned about the emissions released from incinerators. Another disadvantage is the high cost required to keep an incinerator working, but with plans in place to double the number of these rubbish burners in the UK, it seems that waste incineration will continue to be used in the near future.

Your burning question

What happens to our rubbish when it's incinerated?



Pile it up
Waste is deposited inside a large holding area to await incineration.

Dubai has set itself a target of reducing its landfill waste by 75 per cent

Dubai's mega incinerator

In January 2018 Dubai announced its intentions to construct what will be the biggest waste-to-energy plant on Earth. Scheduled to be built in Warsan, United Arab Emirates, the plant will be capable of processing 2 million tons of waste a year, which makes up 60 per cent of the waste produced by the city. This will generate enough electricity to power approximately 120,000 homes in the surrounding district.

Waste collected from around Warsan will be burned at a temperature of 1,200 degrees Celsius in order to thermally treat any potentially dangerous gases contained within the waste, before any remaining fly ash can be released via the plant's chimney.

A potential rival to this superplant has been given the green light in Shenzhen, China. Located in China's southeast, Shenzhen's 20 million inhabitants produce 15,000 tons of waste a day, a third of which will be incinerated within the city's new energy plant upon completion in 2020.

Alfred Fryer – incendiary pioneer

Born in Yorkshire, England, in 1831, Alfred Fryer would one day patent an idea that would revolutionise waste management in the industrialised West, but first he would take an unusual – and rather sweet – career path.

Appointed head of the Manchester-based sugar refinery Fryer, Benson and Forster while in his early 30s, in 1865 Fryer invented a machine known as a 'concretor' designed to solidify sugar cane juice before it was shipped abroad. He then followed this creation up in 1874 while working at Manlove, Alliott and Co Ltd with a patent for a 'destructor', which would later be recognised as the first ever commercial waste incinerator.

A father of four, the inventive Fryer often conducted business in far-flung locations, and he visited destinations including Egypt and Palestine prior to his death in Cheshire in 1892.

The mouth of an incinerator furnace built by Manlove, Alliott and Co Ltd in 1894

Down the chute
Metal grabbing claws methodically collect the waste and drop it into a hopper via a chute.

A release of energy
The heat produced within the incinerator is funnelled into a boiler, while steam is sent to a turbine via pipes, where it will then generate electricity.

Fly ash
Lighter flue gases containing finer ash are diverted to a scrubbing reactor to be cleansed.

Stripping out the metal
Once clean, the gas is piped into a system that will remove any lingering metallic particles.

Up and away
Finally, the gas is expelled out of the plant via a chimney.

Feeding the flames
The hopper slowly filters the waste into the incinerator for burning.

Bottom ash
The weightiest ash filters down into a collection hub, where it is checked with a magnet for reusable metals.

Fly ash particles can contain traces of lethal substances, including arsenic, and must therefore be cleaned thoroughly

50%
The UK is aiming to recycle half of its household waste by 2020

330m tons
Annual disposal capacity of the world's waste-to-energy plants

2kg
The amount of rubbish each person in the US produces every day

1874
The year in which the UK's first waste incinerator was built

80-85%
Amount of solid mass that an incinerator removes from waste

2,450
Number of waste-to-energy plants currently in operation globally

1.2%
Decline in packaging waste recycling or recovery in the UK from 2016 to 2017

267,000m²
Floor space of the waste-to-energy plant set to be opened in Shenzhen, China

How the Nintendo Virtual Boy worked

Take a look inside this shortlived retro virtual reality console from 1995

Nintendo has always been a gaming innovator. From the Nintendo Entertainment System's + shaped directional pad to the Wii's motion controls, the Japanese console-maker is never afraid to take a risk on new technology that changes how we play. And one of its biggest risks was the Virtual Boy – a 3D gaming machine that you placed over your eyes, which was released in Japan in 1995.

Seen now as a precursor to modern VR machines like the PlayStation VR and the HTC Vive, the Virtual Boy was limited by the technology of the time. Rather than powerful 3D sensors and small screens packed with pixels (which you'll find in modern VR headsets), the Virtual Boy used moving mirrors to reflect images into each eye. And rather than connecting up to a separate computer to create rich, immersive 3D worlds that you explore with a turn of your head, the Virtual Boy used plastic cartridges that slotted into the front of the console, containing games like Mario's Tennis and 3D Tetris.

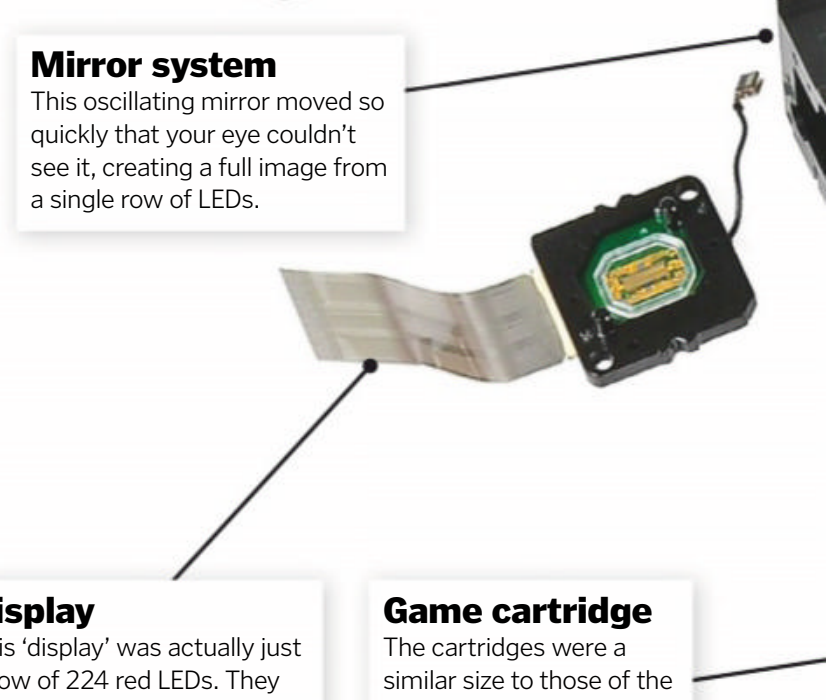
"The Virtual Boy was a precursor to modern VR machines like the PlayStation VR"

Placing your face into the mask and turning on the console, you were greeted by an all-red view. Rather than colour screens, the Virtual Boy used red LEDs to create the visuals for each game. Nintendo wanted to keep costs low, and red LEDs were the cheapest and easiest to see. As a result, games could contain no colour and very little detail – using only black and the three shades of red available. Still, the technology packed into this gaming oddity is still a marvel of its time. We decided to take a look inside Nintendo's retro experiment to see how the first mainstream VR device worked.

The Virtual Boy is a strange-looking console when it's all set up – a first glimpse into a virtual reality future

Controller
In order to let players control 3D games for the first time, Nintendo added a second D-pad to the Virtual Boy controller.

Mirror system
This oscillating mirror moved so quickly that your eye couldn't see it, creating a full image from a single row of LEDs.



Display
This 'display' was actually just a row of 224 red LEDs. They changed hundreds of times a second to create a full image.

Game cartridge
The cartridges were a similar size to those of the Game Boy, and each contained a 32-bit game.

How did the mirror system work?

In order to produce an image that the eye could make sense of, the Virtual Boy used an ingenious solution. The single row of 224 LEDs projected light through a lens. This light hit an oscillating mirror at a 45-degree angle. The mirror oscillated and the LEDs refreshed so quickly that the human eye saw a single image.

Essentially, these LEDs did the work of a full television, one row at a time. The mirror reflected the first row into the players eye, then the LEDs changed to create the second row of the image, and the mirror moved a fraction to project it a little further across. This was repeated 384 times until a full 'image' was produced. It happened so fast that the human eye saw it as a full, moving image – just like you see when you're playing on a TV at home.

DID YOU KNOW? *Only 22 games were made for the Virtual Boy, and of those, only 14 were ever released outside of Japan*

Virtual reality teardown

Nintendo's foray into VR was pioneering gaming technology

Eyepiece
This rubber piece blocked out external light so you could fully immerse yourself in the game.

Depth adjuster
Small switches on the casing enabled you to adjust the focus of the 3D and move the eyepieces closer together if needed.

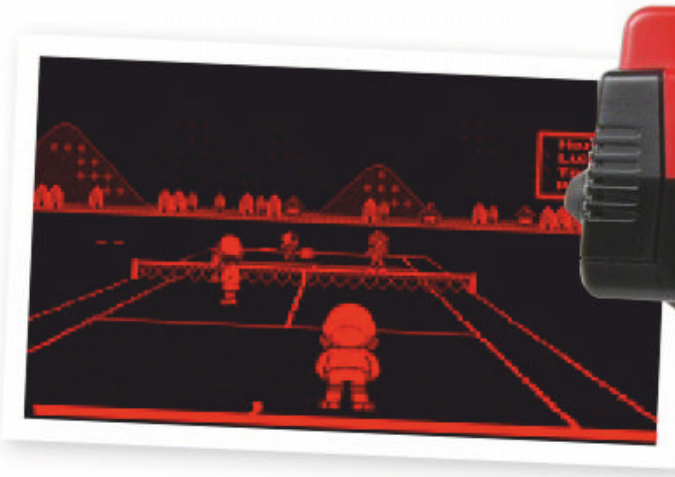
Tripod base
Unlike modern VR headsets, the Virtual Boy remained stationary, held up by a tripod that attached to this.

Display housing
The two small displays and their mirror apparatus were all attached to this plate inside the console.

Controller port
There were no wireless controllers in 1995. This port is where the Virtual Boy's controller plugged in.

Main board
This board took inputs from the controller, loaded game data from the cartridges and drove the two LED displays.

The 3D tech Nintendo used in the Virtual Boy was a precursor to the Nintendo 3DS handheld gaming console that followed much later



Mario's Tennis on the Virtual Boy: some gamers experienced headaches and nausea while playing VB games

How batteries are recycled

There's an afterlife for your dead batteries, and by extracting their much-needed heavy metals we can cut down on waste

The wireless world we live in runs on batteries. Even the smartest phone can't do anything when its power cell is drained until it's empty. The same goes for our cars, laptops, watches or TV remotes. But what happens when a battery dies for good? Alkaline batteries, like AA or AAA batteries, are particularly easy to replace – you just plug in a new one. But you should think twice before simply throwing your old ones in the bin.

All batteries contain heavy metals that are extremely toxic. Alkaline batteries, for instance, contain zinc. Others contain lead, mercury and cadmium. If sent to landfill, these chemicals can escape and pollute the planet. Some batteries give off greenhouse gases as they decompose, contributing to climate change. Others leach their chemicals into the local water supply, poisoning nearby plants, animals and sometimes even people.

Fortunately, these same heavy metals make batteries worth recycling. Our electronics addiction means they can be resold if properly extracted. For instance, laptop power banks can be turned into new batteries, as well as used in the making of paint and in the steel industry. The gypsum from car battery acid can be used in everything from filler for plasterboard to washing powder. Meanwhile, everyday alkaline cells can live on as zinc, steel and plastic components, used in all sort of industries.

Learn more

Find out how you can safely dispose of your dead batteries: **bit.ly/2HUHdDP**

Recharging is the way forward for greener gadgets

Recharge before you recycle

While recycling batteries can help us cut down on chemical waste, it's even better for the environment to not use them in the first place. Rechargeable batteries can replace dozens of everyday AAs, with just one rechargeable battery capable of working for over 1,000 charges.

Of course, you still need to plug a rechargeable battery into the power grid to juice it up, which usually means burning more fossil fuels. And they still contain toxic heavy metals. So how green are rechargeables really?

Well, a 2007 study found that rechargeable batteries use up to 23 times less non-renewable resources than disposable batteries. They also have 28 times less impact on global warming. In both cases, rechargeables are greener due to the sheer amount of energy it takes to mine components for and manufacture new single-use alkalines.

And when a rechargeable battery eventually reaches the end of its life, you can always simply recycle it along with any other battery.

Inside a battery-recycling plant

Discover how dead AAs can be given a new lease of life

© VARTA

1 Disposing of batteries

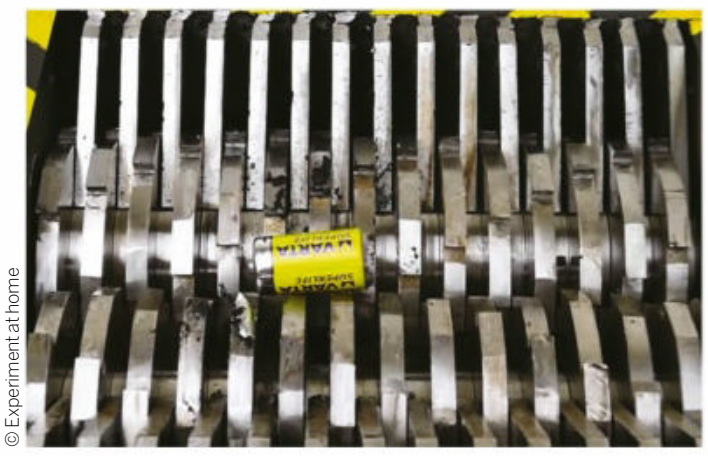
Batteries are collected from drop-off points at supermarkets, hardware stores, recycling centres and elsewhere to be processed en masse.

2 Sorting by hand

Recycling plants sort batteries into groups based on the chemicals they contain, so they can be treated to extract their various materials.

3 Sent to a specialist facility

While AAs are sent to one plant, other types are sent elsewhere – sometimes even abroad – to be chemically treated.



© Experiment at home

4 Mechanical shredding

Alkaline batteries are disassembled by a giant machine and separated into plastics and a black mass core.

© Curbing Jiang

5 Heating the heavy metal

The black mass core is manganese oxide. This is blasted at almost 420 degrees Celsius in a rotary kiln to extract zinc.

6 Making new products

While AA battery casings are reused by the steel industry, the zinc helps make new products, including plastics and ceramics.

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OFFER EXPIRES 30 June 2019

On board the HAWK

The dual-control training jet that helps the next generation of pilots prepare for combat

Words by **Scott Dutfield**

Getting into the cockpit of a jet engine aircraft for the first time is a daunting prospect for any trainee pilot. After spending years learning the theoretical physics and basics of flying, the Hawk is the next stage in their training and their first real venture into the skies, in a working military jet.

The Hawk has played a key training role within the Royal Air Force (RAF) since the 1970s. Originally designed and constructed by Hawker Siddeley Aviation Limited (now known as BAE Systems) in 1971 and first flown in 1974, the Hawk promised a more agile way to fly. It replaced the Folland Gnat, a plane similar in weight and size. However, the Gnat's cockpit only offered a single seat, leaving inexperienced pilots to fly solo. The Gnat saw the end of its training career in 1979 when the new, purpose-built Hawk T1 swooped in to take over.

What makes the Hawk unique for training the next generation of RAF pilots is its dual-control capabilities. Similar to the dual-control cars used by driving instructors, the two-man tandem cockpit enables a teaching pilot to sit behind their student and intervene when needed. For teaching the basics, the jet's cockpit is relatively unchanged since the plane's introduction to the Air Force. Pilots rely on dials, gauges and the view through the glass roof to navigate and fly the plane. However, BAE Systems has integrated multi-functional digital displays in the newer model, the Hawk T2.

Offering an introduction to fast jets, the Hawk is designed to reach Mach 0.88 during flight and Mach 1.15 during a dive. The Mach number relates to the jet's speed when compared to that of sound (equal to Mach 1), so the Hawk can manoeuvre at speeds known as transonic, paving the way for pilot training on supersonic jets such as the F-35 Lightning II.

Although predominantly used as training jet, the Hawk has proven itself as a combat aircraft and has also been used for reconnaissance and surveillance. Currently, around 1,000 aircraft have been sold to 18 countries across the globe.

Aerial acrobats

Though they triumph as a training jet, the Hawk is most recognised as the type of plane seen flying in formation during a Red Arrows display. Originally sporting a black coat of paint, the newly introduced Hawk T1 had a red makeover upon joining the ranks of the Royal Air Force Aerobatic Team in 1979. Debuting synchronised sky routines a year later, the Hawk T1 proved its ability to perform stunning displays.

These gravity-defying stunts, however, can be limited by the weather. In order to carry out the iconic loops, the cloud base needs to be above 1,700 metres so the aircraft avoid entering it and disappearing from sight. If the clouds are lower than that, they're limited to rolling displays, flypasts and steep turns.

An RAF Hawk T1 training aircraft, which has been painted black to make it easily visible and reduce accidents

Inside a RED ARROW

What enables the Hawk T1 to take flight and perform a Red Arrows routine?

11.96 metres
The fuselage length of the Hawk T1

3.6 tons
The total weight of the Hawk T1

1,000 kph
The Hawk T1's maximum speed

Ejection seat
Each plane is fitted with rocket-assisted Martin-Baker Mk.10 ejection seats for use in an emergency.

Dual control
The tandem cockpit is separated into two levels, with the teaching pilot sat in the higher, rear seat, overlooking the trainee pilot.

Weaponry
The Hawk T1 is equipped with a 30-millimetre ADEN revolver cannon.

Airframe
Durable and strong, the Hawk's lightweight airframe is able to withstand the G-forces applied to the plane during manoeuvres.

3.99 metres

The height of the Hawk T1

"A Rolls-Royce Turbomeca Adour jet engine powers the Hawk, producing around 2,400kg of thrust"

Smoke trail

Coloured dye is made by injecting diesel into the path of the jet engine's exhaust, vaporising on contact and producing plumes of smoke.

Aerodynamic

The sleek tail design of the Hawk facilitates the smooth turns and drives during a performance.

Power house

Housed at the rear of the plane, a Rolls-Royce Turbomeca Adour jet engine powers the Hawk, producing around 2,400kg-force of thrust.

2.5 tons

Maximum missile payload

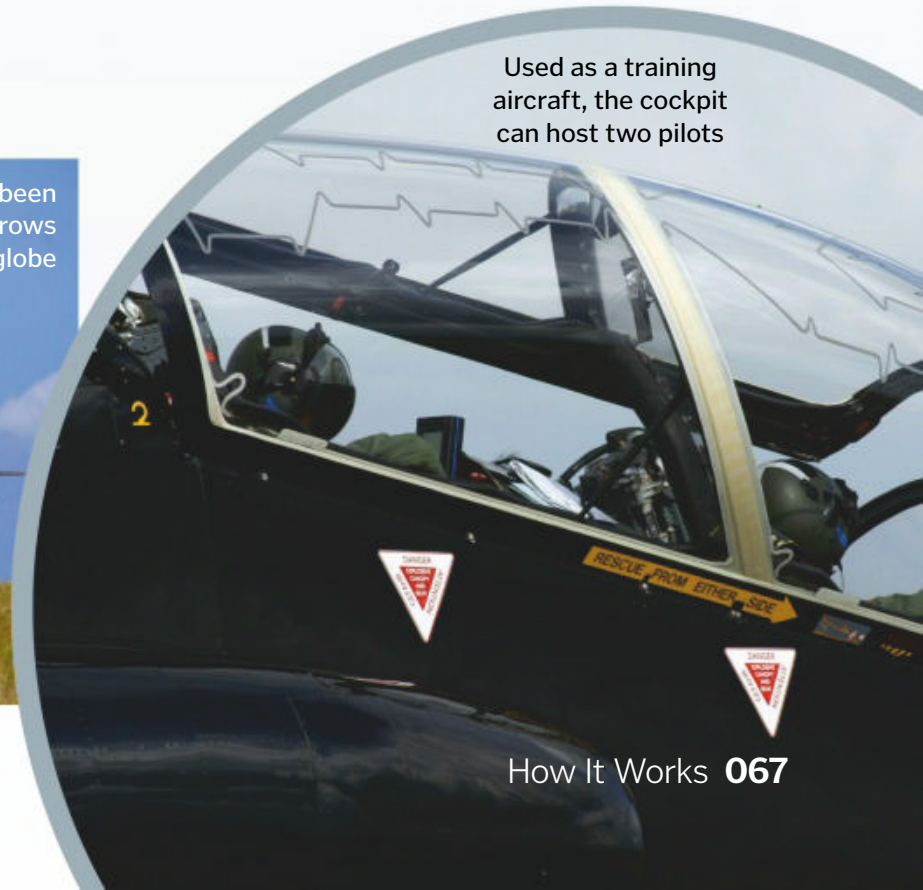
Strong Wing

The T1 is supported with cantilever wings, with a total area of 16.69 square metres.

9.39 metres

The wingspan of the Hawk T1

Since 1979, the Hawk T1 has been the aircraft used in Red Arrows displays across the globe



Used as a training aircraft, the cockpit can host two pilots

Floating haulage

Cargo ships prioritise huge capacity and reliability over speed

Deck crane

Some container ships are fitted with cranes, known as 'derricks', to help load and unload cargo.

Skeleton crew

Thanks to sophisticated computing systems, some of the biggest container ships in the world are manned by just 13 crewmembers.

© Getty

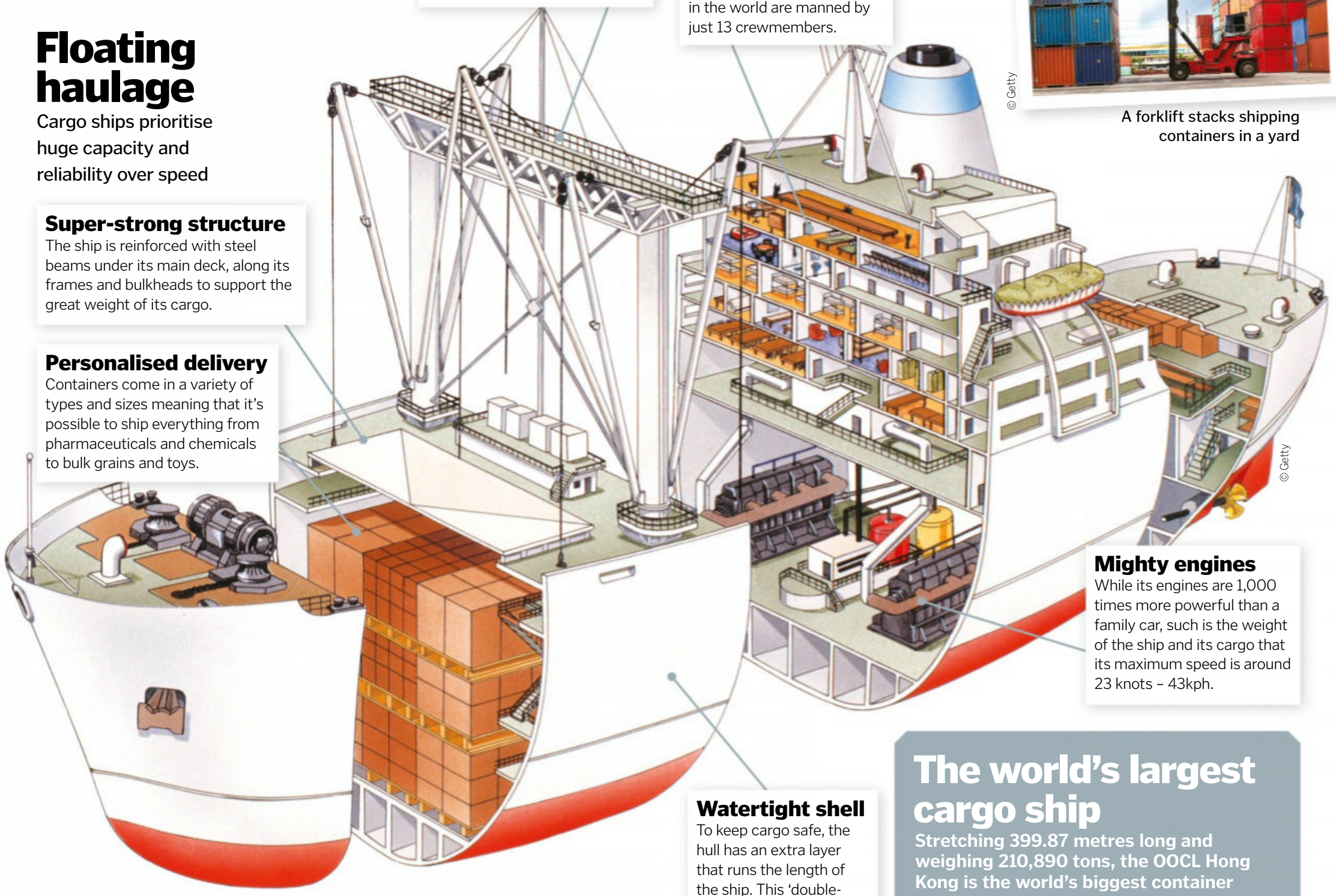
A forklift stacks shipping containers in a yard

Super-strong structure

The ship is reinforced with steel beams under its main deck, along its frames and bulkheads to support the great weight of its cargo.

Personalised delivery

Containers come in a variety of types and sizes meaning that it's possible to ship everything from pharmaceuticals and chemicals to bulk grains and toys.



© Getty

Mighty engines

While its engines are 1,000 times more powerful than a family car, such is the weight of the ship and its cargo that its maximum speed is around 23 knots – 43kph.

Watertight shell

To keep cargo safe, the hull has an extra layer that runs the length of the ship. This 'double-bottom' also holds liquids such as fuel oil, ballast water or fresh water.

See inside a container ship

Explore the floating warehouses that transport the world's goods across oceans

What do your clothes, your laptop and the banana you had for lunch have in common? Chances are, they were all hauled by a cargo ship. In fact, 90 per cent of all goods are shipped this way. These transporters can be nearly 400 metres long – the distance of an Olympic running track. At any one time, these giant floating warehouses are crossing the world carrying at least 20 million containers.

The corrugated steel containers are the key to how modern cargo ships work. Invented by a former trucker, Malcolm P. McLean, in the 1950s, they can be lifted directly from a lorry onto a ship using a crane. They stack on top of each other like building blocks and don't have to be opened until they reach their final destination. This has revolutionised the way we transport almost everything, making it faster and easier.

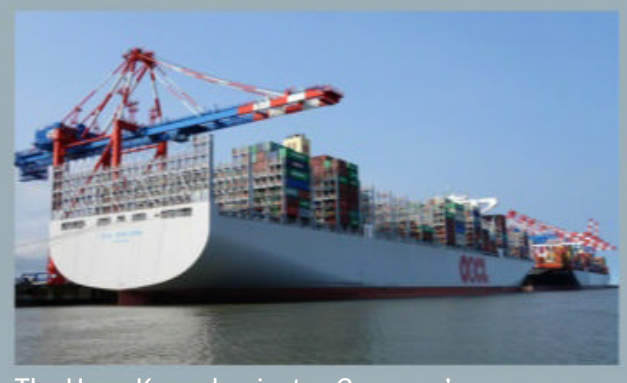
But cargo ships have a dirty secret. While containers have helped to cut the price of global trade, so has 'bunker fuel'. The dregs of the petrol refining process, this low-cost fuel powers many of today's container ships. Heavy with sulphates, bunker fuel means that the 15 biggest cargo ships vent more noxious gases than all the world's cars combined.

New environmental regulations are trying to clean up the shipping industry, ensuring companies use better fuel. Some manufacturers are developing green cargo ships, driven by wind turbines. But this doesn't stop the 50,000 existing container ships from polluting the oceans.

The world's largest cargo ship

Stretching 399.87 metres long and weighing 210,890 tons, the OOCL Hong Kong is the world's biggest container ship. If you could stand this juggernaut upright on its end, it would overshadow even The Shard in London, western Europe's largest skyscraper, by almost 100 metres. Over 58 metres wide, the Hong Kong is also the first ever container ship to be able to carry more than 21,000 standard shipping containers.

The mega-vessel transports goods from Shanghai, China, to Felixstowe, UK, and back again. With a cruising speed of 14.6 knots (27kph), and also calling at ports in the Netherlands, Singapore and elsewhere, it takes 77 days to complete the journey. The Hong Kong is the second record-breaker for Orient Overseas Container Line, with the operator's OOCL Shenzhen (capable of carrying 8,063 containers) briefly claiming the title of largest-ever container ship in 2003.



The Hong Kong dominates Germany's JadeWeserPort in 2017

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FROZEN TIME

The incredible ways nature has preserved prehistoric humans and beasts for us to find today

Words by **Amy Grisdale**

ZEN

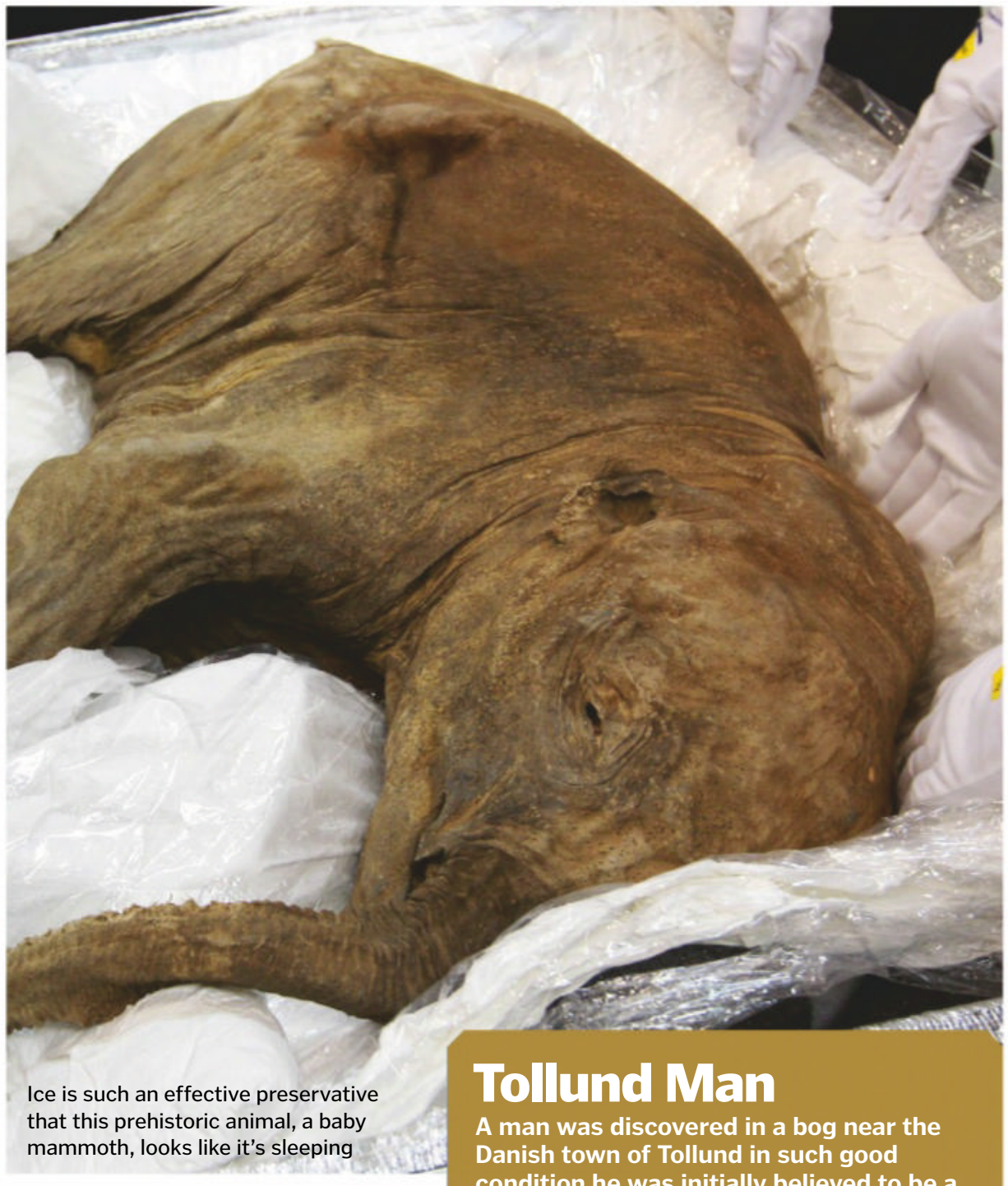
Borremose Man
This body, dating from around 840BCE, was found preserved in a peat bog in Denmark in 1946

The Earth has experienced monumental changes since it was formed some 4.5 billion years ago. It has undergone alternating phases of cooling and warming, and this swinging between extremes of temperature dramatically changed the ecosystem. It brought about mass extinctions and the chance for new species to evolve in their place. The animals that ceased to exist left impressions, from partial footprints to intact fossilised skeletons. In some circumstances, however, animals of the past found their way into environments that preserved their entire bodies while the rest of the species rotted away.

One excellent method of animal preservation is freezing. Cold weather grinds the speed of organic decomposition to a halt by preventing the growth of bacteria that would otherwise feed on the decaying flesh. Temperatures were five to 22 degrees Celsius colder than today's climate in the most recent ice age. Animals were well-insulated with thick hair, such as the great woolly mammoth, or took shelter from the cold

Carcasses trapped in tar pits attracted carnivores, who also got stuck in the sticky substance

Tusk hunters are always on the trail of precious prehistoric ivory



Ice is such an effective preservative that this prehistoric animal, a baby mammoth, looks like it's sleeping

like cave lions. Now most of the world has defrosted, but there are still areas that remain frozen, such as parts of Russia and Asia. Animals that lived and died in this bygone era have since been plucked from permafrost (a permanently frozen layer in the ground) with their bodies intact. A steppe bison that lived 36,000 years ago was uncovered in pristine condition in 1979. Its rear end still bore the claw and tooth marks from the Ice Age lion that killed it.

Specimens that have survived thousands of years often became trapped somehow before a sudden plummet in temperature. The presence of food in the stomachs of Ice Age animals indicates that their bodies were frozen rapidly, preventing decay.

A large proportion of frozen remains are unearthed by miners on the hunt for precious metals. Scientists are invited to remove and study the remains, and are able to draw conclusions about how the animal lived day to day and what may have led to its extinction. Scrutiny of a woolly rhino found by gold miners in northern Russia in 2007 convinced researchers that the species died out because its legs were too short to move efficiently through deep snow.

"Lack of oxygen, low temperature and acidic water worked together to 'pickle' animal remains"

In the absence of ice, nature has other ways to preserve body tissue. An extremely important factor in preventing decomposition is separation from oxygen. Europe's peat bogs have a magical combination of a lack of oxygen, low temperature and acidic water, which works to 'pickle' the remains of any animal that meets its end in the mud. Over time, layers of moss form on the bog's surface and release chemicals that halt bacterial growth.

Some of the most famous remnants of the past uncovered in these bogs are almost immaculately preserved human remains, along with a plethora of bizarre ancient artefacts that have been recovered in recent years. Huge hunks of an edible waxy substance are sometimes found with these 'peat-bog men' that are thought to be made of dairy or meat. This

Tollund Man

A man was discovered in a bog near the Danish town of Tollund in such good condition he was initially believed to be a recent murder victim. The body had been lying in rest for some 2,300 years, still dressed in primitive clothing. He appeared to indeed have been murdered, but the culprits themselves were long dead. Peat bogs may have been ancient grounds of burial or even ritual sacrifice. 'Tollund Man' was found with a braided leather cord wrapped tightly around his neck, and it's unclear whether he was hanged or strangled. The absence of trees across stretches of bog may have made people feel a connection to the heavens and therefore made it a place of religious significance.

Tollund man is so well preserved, even his last facial expression is clear

Bog embalming

Chemicals in Europe's bog waters are a perfect mix for preservation

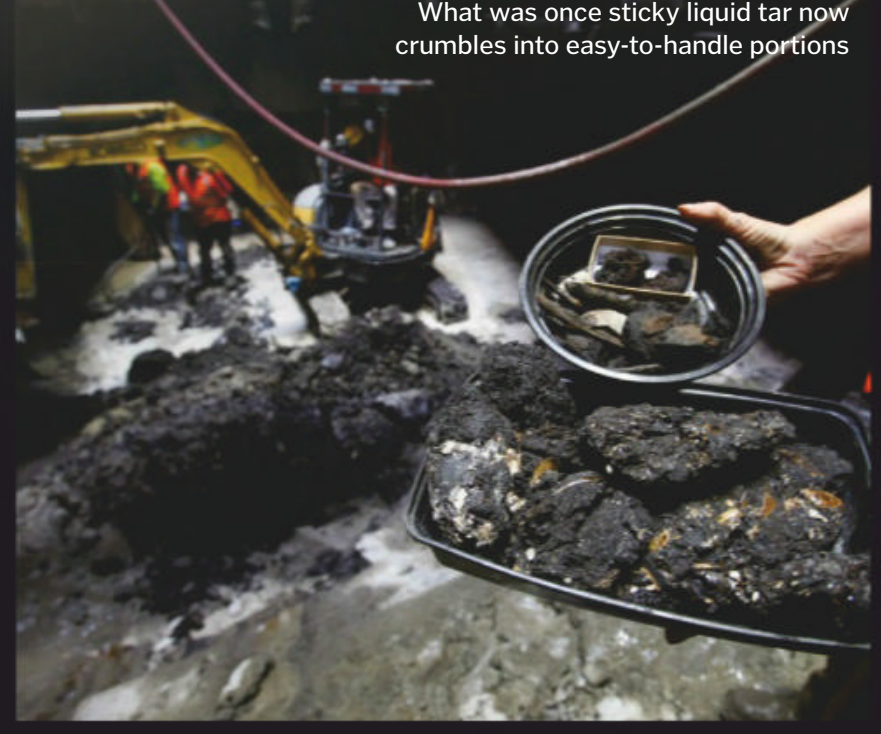
No air
At depths of 30-50 centimetres there is no oxygen left in the acidic soil. Bacteria cannot break the body down.

Raised bed
Elevated bogs contain the least oxygen but the most acid. These are the best at keeping a body fresh.

Sphagnan
Decaying moss releases a carbohydrate called sphagnan. This polymer extracts calcium from the bones, leaving the body soft and squishy.

Under pressure
The weight of the water forces the peak soil to pack together tightly and nestle closely around the person.

The Tollund Man was killed with this leather rope, and his hat is made of skin



What was once sticky liquid tar now crumbles into easy-to-handle portions

Types of fossilisation

There are many ways animals and plants can be preserved or altered by the environment

Ash

Clouds of volcanic ash bury remains of living beings without crushing or burning them, causing less damage. The remains of the city of Pompeii sat under a heap of ash for 1,669 years, and the people who had been buried by the ash were preserved with remarkably little alteration.

Ice

Ice is an amazing tool for preservation. No parts of the body are replaced when frozen. A normal human body can decompose in as little as eight years if it is buried in soil, whereas corpses are known to have lasted for 5,000 years or longer when they have been buried in ice.

Asphalt

Crude oil seeps out of the ground, slowly forming pools on the surface. The oil becomes more viscous and sticky, trapping animals that come into contact with it. Bones that have soaked in tar are stained a tan colour, but otherwise are preserved without being affected by the environment.

Carbonisation

The carbon in a soft-bodied animal creates an impression in sedimentary rock while the rest breaks down. A detailed carbon stamp remains on the surface, to be discovered later on. The majority of fossilised feathers are preserved as carbonised traces.

Sediment

Mud sitting at the bottom of a lake or a river envelops carcasses of fish and invertebrates. It can accumulate and bury a dead animal very quickly, denying it oxygen and preserving the creature's flesh. Many millions of years can pass before it is once again exposed to the surface.

Amber

Tree resin solidifies as amber, and animals can get stuck inside – just like the mosquitoes in *Jurassic Park*. Insect exoskeletons, made of the protein chitin, emerge almost unchanged. Unfortunately, however, the inner soft tissue is not preserved.

Peat bog

Around 100 bodies have been found preserved in peat bogs, a quarter of which are considered to be in exceptional condition. The remaining 75 that have been found are skeletons. They are from northern Europe, especially Ireland, the UK, Denmark, Germany and the Netherlands.

Petrification

This is the process through which organic material is slowly replaced by minerals. The remains are completely altered by this process, and the fossils that are produced are really stony replicas of the organic original.

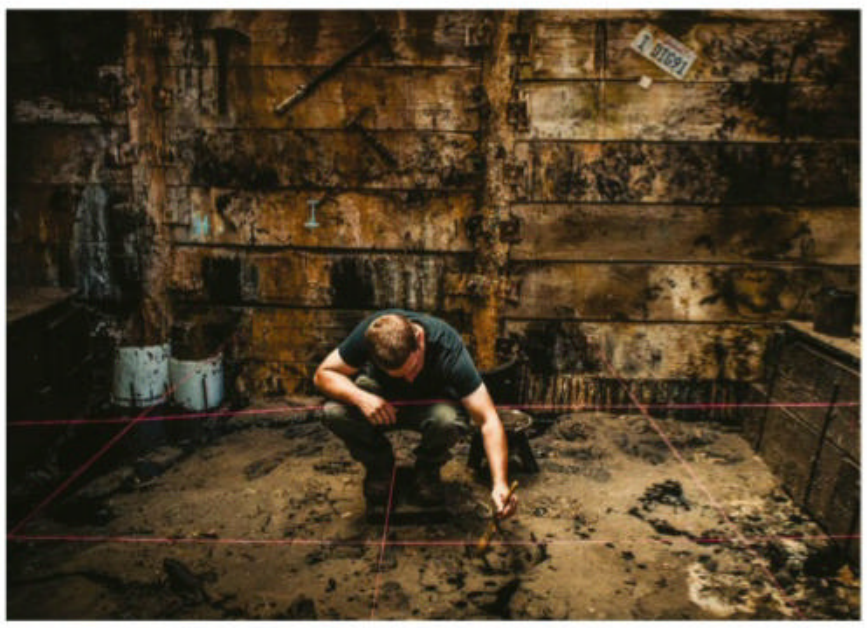
'bog butter' may well have been a treasured food product to slather on Bronze Age bread. It's possible that people of the past stored their butter in bogs to keep it cool and fresh, long before the days of refrigeration. It worked so well that this ancient spread is thought to still be edible – so long as the diner can ignore the smell.

Animals can get locked in a kind of time capsule by getting stuck in tar pits. In some parts of the world, springs of natural asphalt can seep up to the ground as thick crude oil. It accumulates and eventually forms a pool, the surface of which reacts with air to become thicker and stickier. We call these tar pits, and each one is a snapshot back in time. Prehistoric animals would get trapped and struggle to free themselves. The resulting commotion would then attract predators, some of which would be lost in the tar themselves. Thousands of years later, the solidified tar began to be mined as asphalt, and the treasures within came to light.

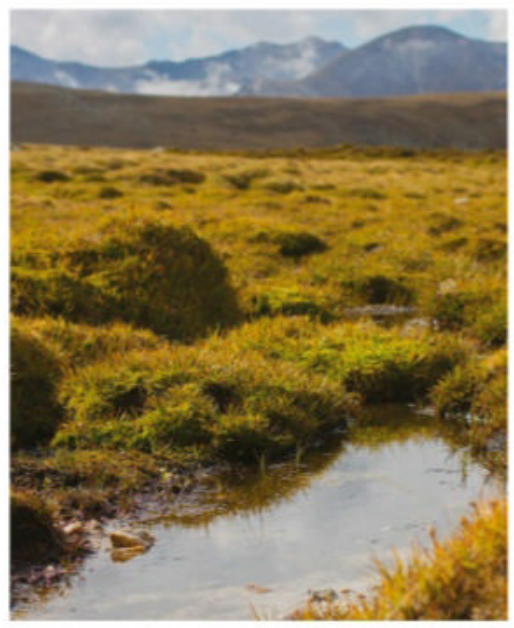
"Prehistoric animals would get stuck in the tar and struggle to free themselves"

La Brea is a world-renowned tar pit in Los Angeles, California. It trapped creatures for over 30,000 years, and new discoveries are still being made to this day. The site has been under excavation since 1913, and over 3.5 million specimens have been been found so far. More than 600 species of animals and plants have been identified from these remains, but most discoveries were bones of large animals. 90 per cent were carnivores like American lions and dire wolves. 4,000 dire wolves have been retrieved from the tar, and some 400 of their skulls are on display at the George C. Page Museum that stands on the excavation site.

Humans have learned so much from these pockets of prehistory. We have pieced together the events of evolution and have a detailed understanding of how we reached today. Chunks are missing, but areas that have preserved the past are helping us fill in the blanks.



The La Brea tar pit contains thousands of examples of preserved prehistoric creatures



Peat bogs, unremarkable at first glance, contain incredible pieces of history

How tar preserves prehistoric animals

Low-grade crude oil seeps out of the ground, encountering air for the very first time. Contact with oxygen enables small and simple hydrocarbon chains to degrade or evaporate. As the lighter fractions of oil disappear, the remainder is purer and is less likely to escape. The tar begins to harden when it touches the cool air but remains viscous enough for a heavy animal to sink in.

Dust, leaves or even water can camouflage the tar's surface, making it easy for a wandering mastodon (a kind of prehistoric elephant) to stray into a natural vat of tar. It calls out to other members of its species for help, inadvertently alerting wolves and big cats to its plight. Even if it dies of starvation or dehydration, it takes up to 20 weeks to sink. During this time, it is visited by hungry predators that are then at risk of getting stuck themselves.

The George C. Page Museum opened in 1977, and an excavation is underway that has the potential to double its collection

Five incredible ice mummies

These frozen prehistoric animals are superbly well-preserved and now famous around the world

Sasha

This woolly rhino baby was the first young member of its species ever found. It's unclear if it is male or female, but the horn size suggests it had been weaned by the time it died. It roamed the mammoth steppe, a dry, cold region from Spain to Siberia.

Lion or lynx

A squashed, mummified cat was unearthed in eastern Siberia in 2017. It could either be a lynx kitten or a cave lion cub. Its coat is in beautiful condition, but we can't be sure of the species as we simply don't know what a cave lion truly looked like.

Death by drowning

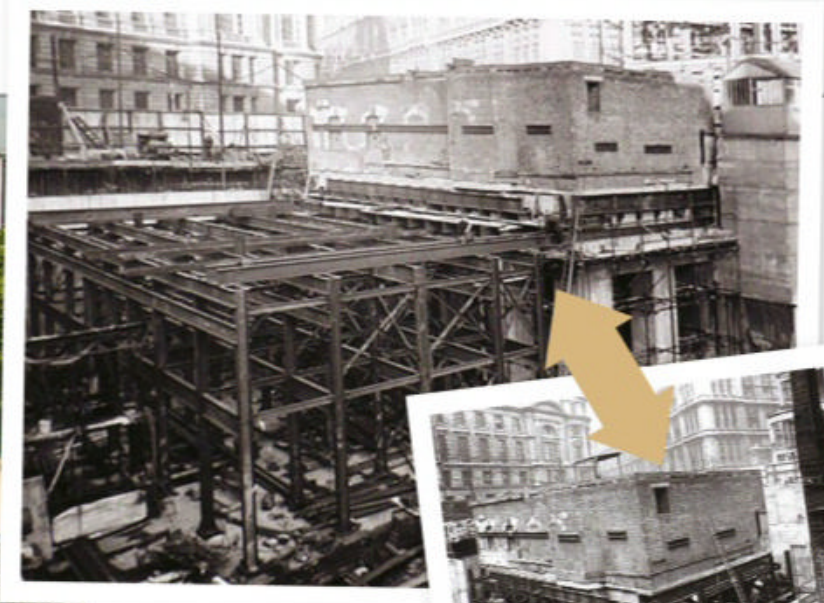
Mammoths from 40,000 years ago have been studied via CT scans. The results showed that two calves, recovered from different regions of Siberia, had both choked on mud. They otherwise appeared plump and healthy.

Old but good

The most complete steppe bison specimen ever found is 9,000 years old. It has a complete heart, brain and digestive system, along with near-perfect blood vessels. Some organs have shrunk over time but are remarkable nonetheless.

Frozen foal

A two-month-old horse was found buried approximately 100 metres deep in a Siberian crater. In life it stood almost one metre tall, and its hooves are still intact, along with tiny hairs that are still visible inside the foal's nostrils.



The wine cellar in the process of being moved

Henry VIII's party palace

Almost all traces of England's spectacular Palace of Whitehall are long gone. So when the party king's wine cellar was discovered, it had to be moved for it to survive

In 1529, England was on the brink of complete crisis. Its monarch, King Henry VIII, had fallen head over heels in love with the beautiful Anne Boleyn, and he was determined to marry her. There was one slight hitch: Henry was already married. Catherine of Aragon had been his wife for 20 years, but the union had failed to produce a male heir, and Catherine, in her mid-40s, was past child-bearing age. Almost two decades younger, Anne was the picture of youth and could give the king the son he so desired – if he could get rid of Catherine.

Henry plotted an escape from his marriage, turning to his councillors to find a solution. But not all of his allies supported his scheme. Cardinal Thomas Wolsey, the archbishop of York, was tasked with acquiring the pope's approval for an annulment, but when Wolsey failed he was accused of dragging his heels and was quickly arrested for treason. With Wolsey fallen from grace, King Henry took possession of York Place, the archbishop's extravagant residence – so splendid it rivalled even the king's palaces.

Henry moved into York Place and continued to extend and improve the residence, renaming it the Palace of Whitehall and turning it into the crowning glory of his collection of royal residences. It was here, in the Palace of

Finding a hidden history

When building work for the new Ministry of Defence building began, long-forgotten remnants of the royal palace resurfaced, including a terrace by the queen's apartments on the bank of the River Thames, as well as steps leading down towards the river to provide easy access to the state barge. The river wall of the Thames was moved to make way for the building, but with the burning of the palace in 1698 and the redevelopment of the area into townhouses, this unique feature remained hidden until the site was cleared for the Ministry of Defence Main Building.

Deciding whether or not to preserve the steps became a point of contention – some parts of the river wall interfered with the actual walls of the new building construction, but the feature itself was the only surviving part of the palace designed by Sir Christopher Wren, arguably the greatest architect in British history. In the end, it was agreed that a small section of the river wall and terrace would be preserved, as well as the steps.

The terrace and steps, created by Sir Christopher Wren, can still be seen outside the MoD building

Intrigue and fire

1241
The archbishop of York acquires a building near the Palace of Westminster and names his new residence York Place.

1514–1529
Thomas Wolsey, the cardinal of York, extends York Place hugely, making it one of the biggest and most impressive houses in the whole country.

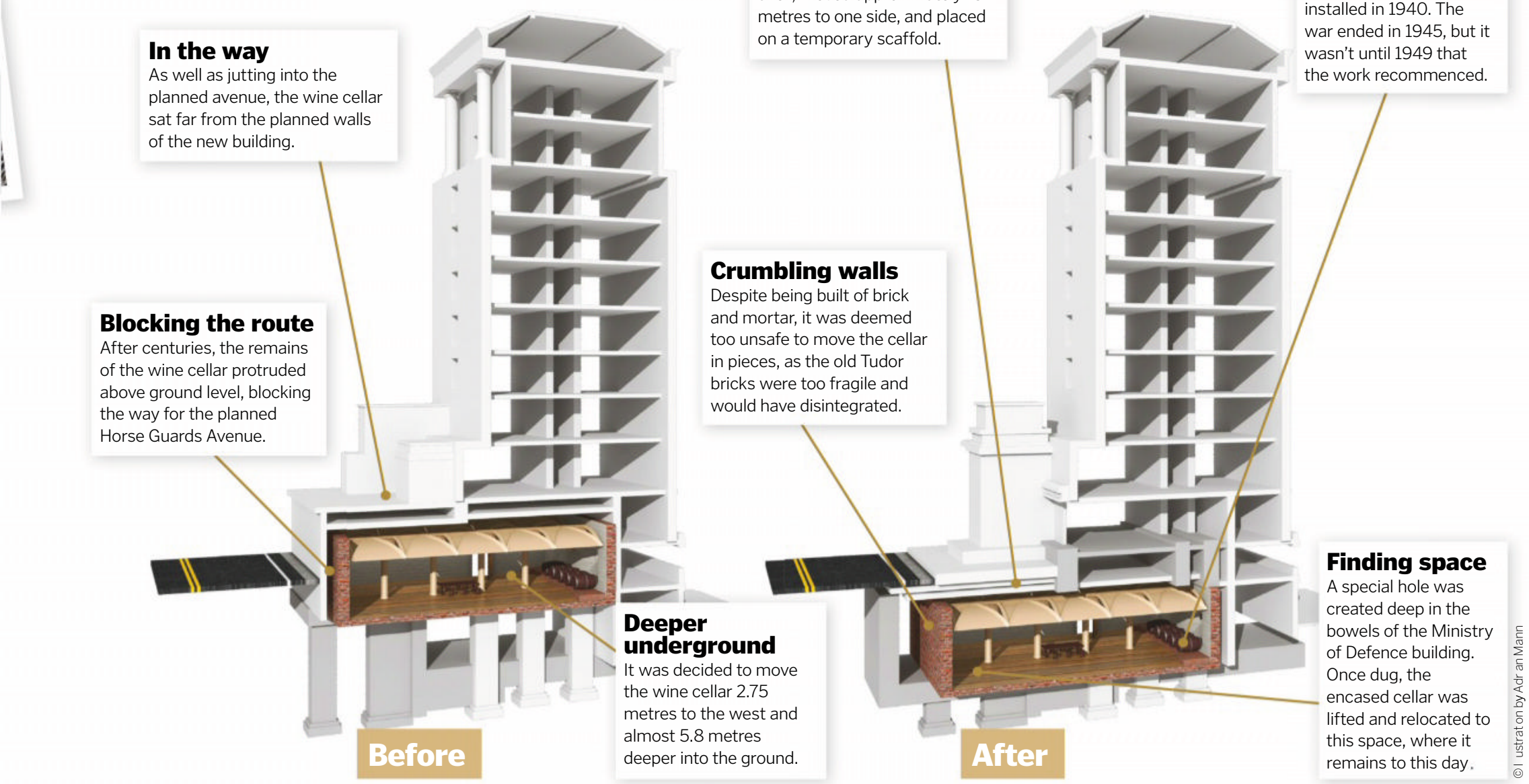
1529
Upon Wolsey's fall from grace, King Henry VIII confiscates the house from the archbishop and moves in just two days after his former ally's demise.

1533
The newly renamed Whitehall serves as the venue for Henry VIII's clandestine wedding to Anne Boleyn in 1533. Henry marries Jane Seymour here in 1536, just 11 days after his unfortunate former wife's execution.

1558–1603
Under Queen Elizabeth I, Whitehall becomes the diplomatic heart of England, where the queen's potential marriages are negotiated.

Moving the cellar

When it became clear that the old wine cellar didn't fit with the new plans for the Ministry of Defence building, an incredible plan to relocate it was approved



In the way
As well as jutting into the planned avenue, the wine cellar sat far from the planned walls of the new building.

Blocking the route
After centuries, the remains of the wine cellar protruded above ground level, blocking the way for the planned Horse Guards Avenue.

Deeper underground
It was decided to move the wine cellar 2.75 metres to the west and almost 5.8 metres deeper into the ground.

Crumbling walls
Despite being built of brick and mortar, it was deemed too unsafe to move the cellar in pieces, as the old Tudor bricks were too fragile and would have disintegrated.

The big hoist
The entire wine cellar was encased in a concrete and steel shell, moved approximately 13 metres to one side, and placed on a temporary scaffold.

A pause for war
In 1939, when World War II broke out, work on the new building and the wine cellar were paused, with underpinning installed in 1940. The war ended in 1945, but it wasn't until 1949 that the work recommenced.

Finding space
A special hole was created deep in the bowels of the Ministry of Defence building. Once dug, the encased cellar was lifted and relocated to this space, where it remains to this day.

Before

After

© Illustration by Adrian Mann

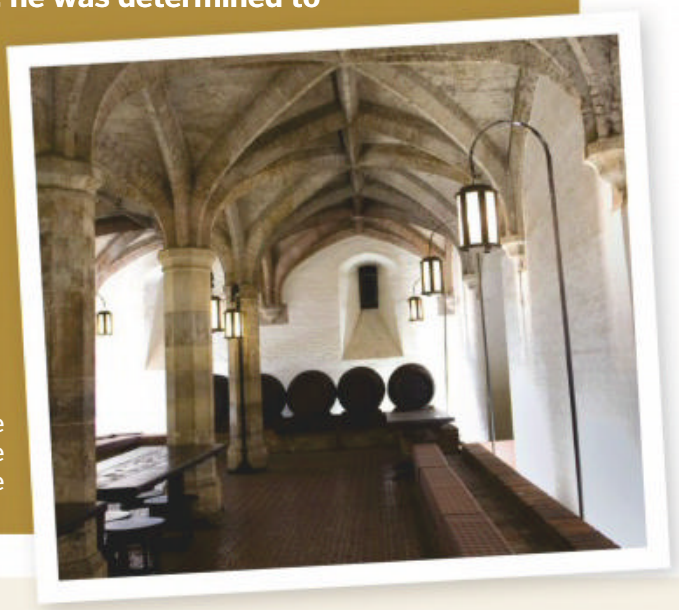
Whitehall, where Henry threw lavish parties, married two of his six wives and died in 1547.

For the next century and a half, The Palace of Whitehall remained a royal residence, with several kings and queens calling it home. The remarkable history of this exceptional palace was cut short, however, in 1698, when a devastating fire razed almost the entire complex to the ground. The only survivors of the inferno were the Banqueting House and Henry VIII's old wine cellar.

Rebuilding the palace proved to be too costly, so over the next couple of centuries the site was built over with townhouses. In the early 20th century, it was decided that a governmental building would occupy the space where Whitehall had been, but the wine cellar posed a very particular problem...

How Henry became the party king

When Henry VIII inherited the throne from his father, he also took control of the royal coffers, filled to the brim with money thanks to his father's frugality. But Henry VIII was a very different king to the kind his father had been. Henry immediately set about reversing the austerity that had been the plague of his father's court; he was determined to bask in the splendour of royalty, throwing tournaments, banquets and parties, funded by his father's nest egg – and, of course, by taxes. In fact, it's been suggested that in his first year of being king, Henry spent the modern-day equivalent of £13.5 million on hosting extravagant parties – over 80 per cent of the country's total revenue. Of this, almost £6 million went on ale and wine. Over 300 barrels of wine were shipped to the king each year, imported from the south of France where the finest vintages was made.



Henry VIII's wine cellar would've been filled to the brim with wine, the most expensive of which were imported from the south of France

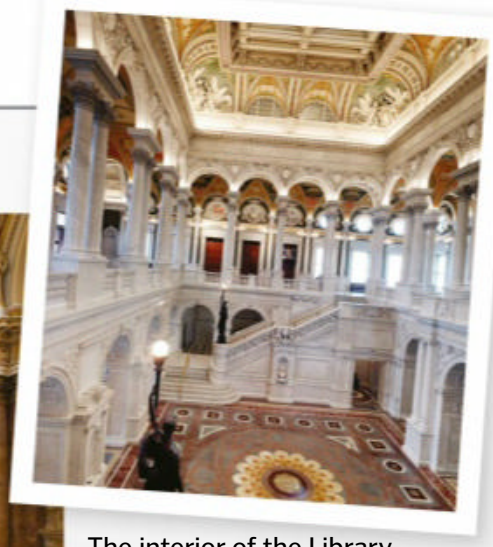
1619–1622
King James I commissions Inigo Jones to design and build a new Banqueting House. Jones's creation – which still stands today – is celebrated across Europe.

1649
On a wooden platform erected outside of Whitehall's Banqueting House, King Charles I is beheaded, having been sentenced to death for high treason.

1698
An inferno, which starts when linen hung to dry in front of a brazier catches fire, tears through the palace. After blazing for 15 hours (and reigniting the next day), almost all of the palace is in ruins. To this day, only the Banqueting House stands.

1938
In keeping with the Dowager Queen Mary's wishes, Henry VIII's wine cellar is preserved and relocated so that it doesn't impact the development of the Ministry of Defence Main Building.

The Main Reading Room in the Thomas Jefferson Building



The interior of the Library of Congress is truly grand

Inside the Thomas Jefferson Building

Take a peek at the main building of the Library of Congress

African & Middle Eastern Reading Room
This room, home to the division of the same name, is where materials can be read in Arabic, Armenian, Georgian, Hebrew, Persian, Turkish and Yiddish, among others.

Northwest Pavilion
In each corner of this pavilion, relief sculptures represent the four seasons. Meanwhile, Ambition and Fame are depicted on the ceiling, and murals feature literature, art, science and music.

Great Hall
Upon entering the Library of Congress, you are greeted with a magnificent entrance hall that features works of art from around 50 American painters and sculptors.

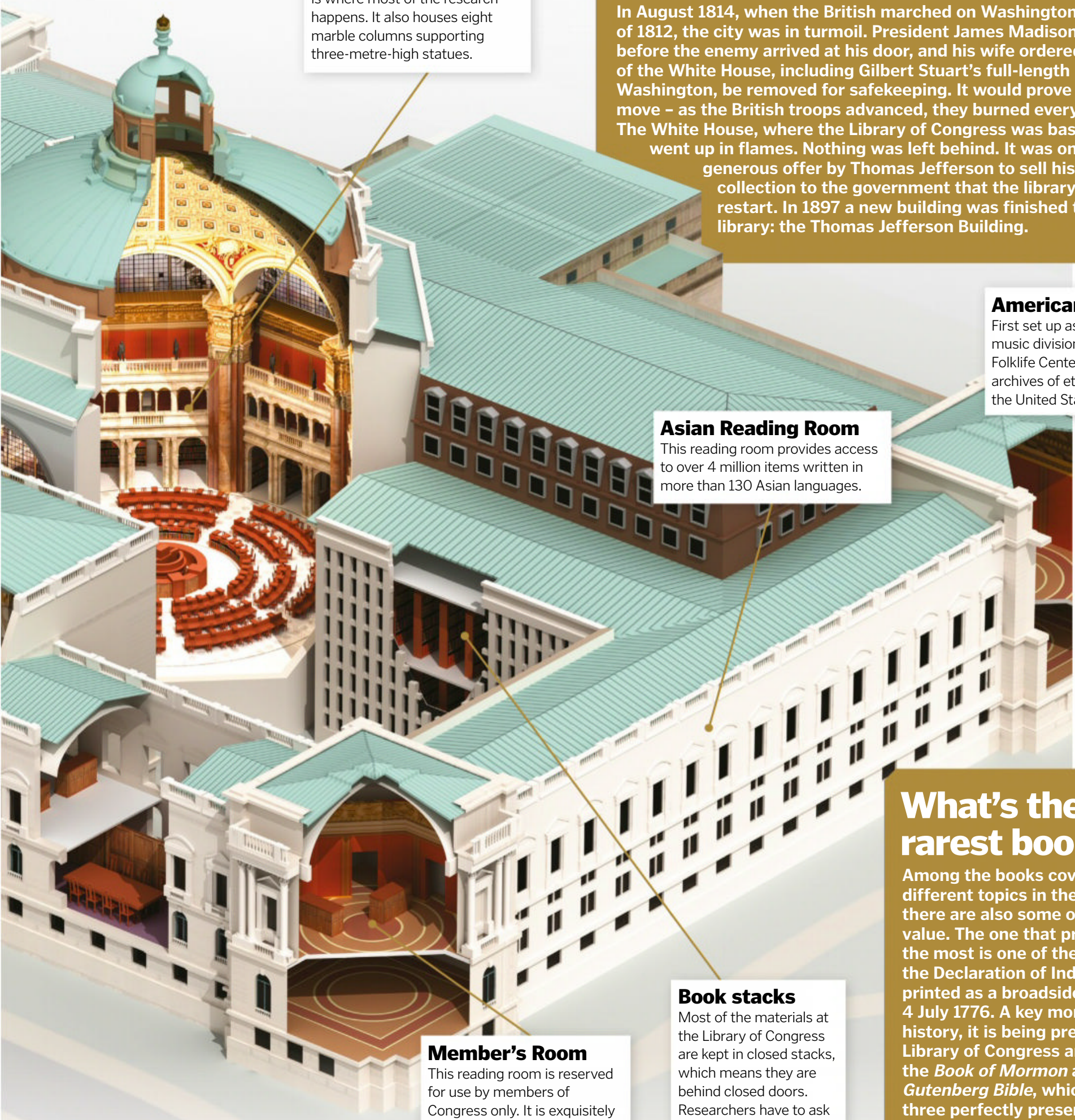
What is the Library of Congress?

Explore the largest national library in the world

The biggest library in the world can be found on Independence Avenue in Washington DC, the capital of the United States, and it's as impressive as you would expect. It comprises three buildings – named after famous presidents Thomas Jefferson, John Adams and James Madison – and are connected by underground passages. Between them, they house more than 168 million items, including more than 39 million books and other print items in 470 different languages, over 72 million manuscripts, the world's largest law library which has over 2.9 million volumes and the largest rare book collection in North America.

It's the oldest federal cultural institution in the United States, but why does Congress need a library? Simply, with so many different books, manuscripts, sound recordings and so on, the library is able to help inform the debates of lawmakers by providing authoritative research and analysis on almost any subject. Librarians have put together resource and research guides over the years on everything from contract law and federal legislative history to Abraham Lincoln and Rosa Parks. You can also find primary documents from throughout American history and more modern resources on international events such as Brexit.

The main mission of the Library of Congress is to help with research enquiries made by members of Congress – it responded to more than 1 million reference requests in 2018 – and only high-ranking government officials and employees of the library itself are able to check out books. However, the public are free to use the site and its 21 reading rooms.



Main Reading Room
As the name suggests, this room is where most of the research happens. It also houses eight marble columns supporting three-metre-high statues.

Asian Reading Room
This reading room provides access to over 4 million items written in more than 130 Asian languages.

Member's Room
This reading room is reserved for use by members of Congress only. It is exquisitely decorated with oak panelling and Italian Siena marble.

Book stacks
Most of the materials at the Library of Congress are kept in closed stacks, which means they are behind closed doors. Researchers have to ask librarians to find what they're looking for.

American Folklife Center
First set up as an archive in the library's music division in 1928, the American Folklife Center is now one of the largest archives of ethnographic materials from the United States and around the world.

When Brits burned the books

In August 1814, when the British marched on Washington DC during the War of 1812, the city was in turmoil. President James Madison fled only hours before the enemy arrived at his door, and his wife ordered that the treasures of the White House, including Gilbert Stuart's full-length portrait of George Washington, be removed for safekeeping. It would prove to be a shrewd move – as the British troops advanced, they burned everything in their path. The White House, where the Library of Congress was based at the time, went up in flames. Nothing was left behind. It was only thanks to a generous offer by Thomas Jefferson to sell his private book collection to the government that the library was able to restart. In 1897 a new building was finished to house the library: the Thomas Jefferson Building.

What's the rarest book?

Among the books covering countless different topics in the library's collection, there are also some of great historical value. The one that probably stands out the most is one of the original copies of the Declaration of Independence that was printed as a broadside by John Dunlap on 4 July 1776. A key moment in American history, it is being preserved in the Library of Congress archives alongside the *Book of Mormon* and a version of the *Gutenberg Bible*, which is one of only three perfectly preserved vellum copies to exist in the world.

From the ground up

1886
The ground is cleared for the first building of the Library of Congress.

1889
The foundations are dug to support the building.

1890
The walls begin to go up in 1890 with the help of cranes.

1891
After another few months, the walls start to take a little more shape.

1891
As the building grows taller, the shape of the windows become clear to see.

1891
The first floor is finally completed in October 1891.

1892–93
Construction begins on the dome that covers the Main Reading Room in the centre of the Thomas Jefferson Building.

1893
The dome, complete with the symbolic Torch of Learning on top, is finished. Building continues until 1897, when the new Library of Congress finally opens on 1 November.

Tiger tank anatomy

Nazi Germany's ultimate heavy panzer was designed to strike a decisive blow for the Third Reich

The Panzerkampfwagen VI, more commonly known as the Tiger I, was developed in the early 1940s with the aim of creating an unstoppable armoured killing machine for the German military. Two rival engineering companies, Porsche and Henschel, were approached to produce prototypes for the tank, meeting specifications such as weight, cost and weapon capability. Henschel's design was eventually selected and rushed onto the production line in order to quickly deploy on the Eastern Front, joining Hitler's ongoing invasion of the Soviet Union.

It took five crewmembers to operate the Tiger: a driver, gunner, loader, commander and radio operator. The tank's main weapon was a 88mm gun, which was originally designed as an anti-aircraft artillery piece. At the time of the Tiger's first deployment, this huge cannon was capable of penetrating any enemy armour from long range. Years after its first deployment, during the Battle of Normandy in 1944, this enabled Tiger crews to ambush Allied formations from a distance, unleashing devastating fire before their enemy had a chance to respond.

The Tiger's armour was 100mm thick at the front – strong enough to stop or deflect nearly any Allied return fire. Battlefield accounts of Tigers in combat report round after round of enemy fire failing to penetrate this formidable shell. Unlike another prolific German tank, the Panther V, the steel plate protection of early Tigers was not angled, which provided less protection. This angled design feature was later added to the King Tiger, which was completed in the final months of the war – too late to prevent the defeat of Nazi Germany.

Despite its fearsome reputation on the battlefield, the Allies were eventually able to counter the Tiger I's capabilities – outnumbering, outmanoeuvring and eventually outgunning the once-dominant machine. Today, the Tiger remains among the most iconic vehicles of WWII and a milestone in the history of armoured warfare.

A still from a Nazi propaganda film showing a formation of Tiger II tanks

MG 34
To the right of the driver, the radio operator would also use the 7.92mm machine-gun, mounted in the front of the hull.

Turret
The loader, gunner and tank commander would all occupy the turret, which could also be armed with an additional MG 34.

Armour
Armour plating was over 100mm thick at the front, but the hull was much weaker at the sides and rear.

Driver
The driver's seat was at the front left, with a forward-facing viewing hatch that could be closed during combat.

88mm gun
Originally designed for anti-aircraft purposes, the Tiger's huge cannon had a devastating range and armour-piercing capability.

A paper Tiger?

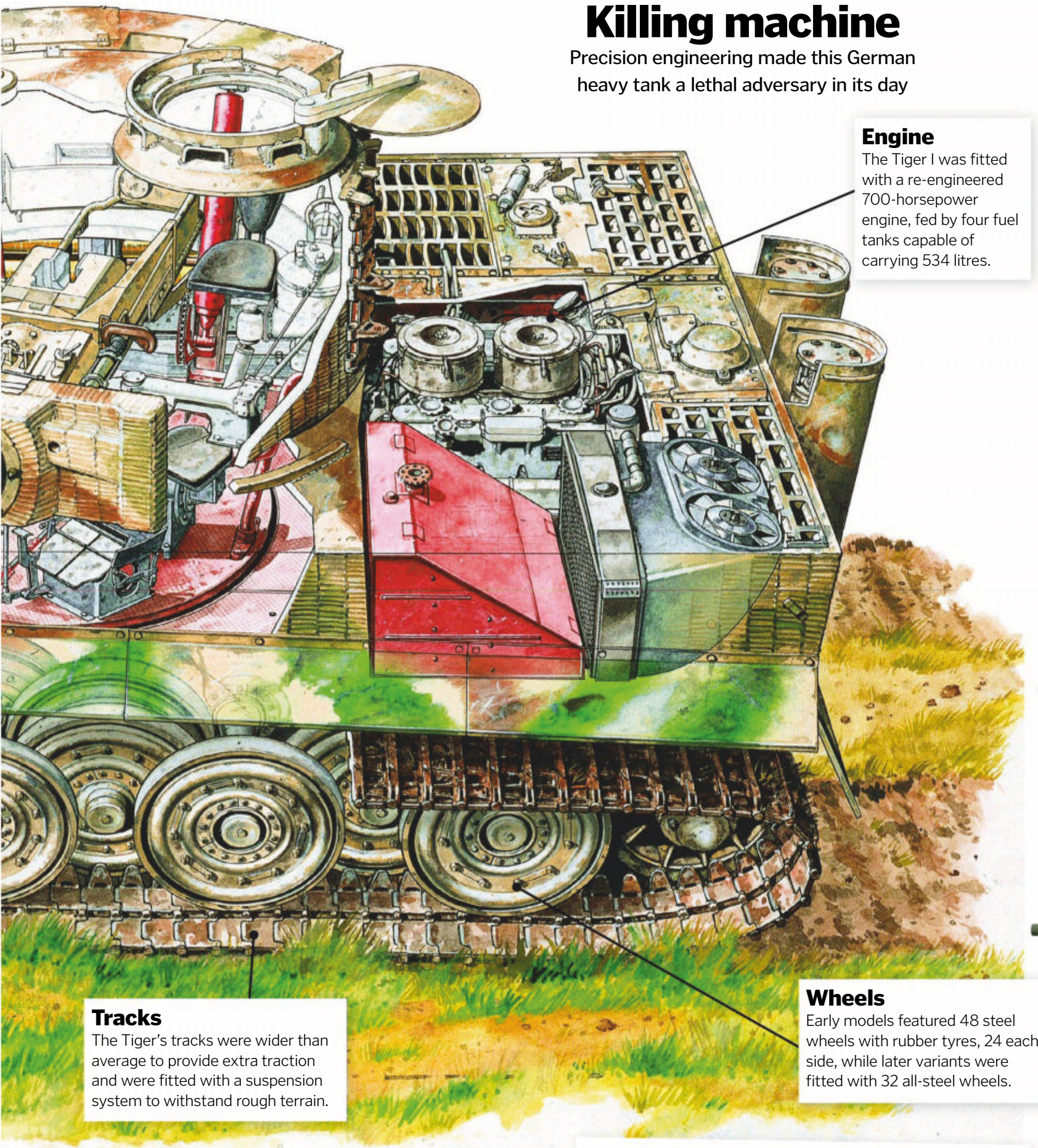
Although the armour and weaponry of the Tiger posed a formidable threat on the battlefield, the tank never struck the decisive blow so desperately desired by the German high command. Among the main challenges to the Tiger was the number that could be deployed. Germany's military factories became targets for Allied bombers, and key components for the tank's production became delayed, meaning fewer were ready to join the frontline than expected.

In addition, the tank's size and complexity, including the innovative suspension system, made it much more expensive and time-consuming to produce. High fuel consumption was also a major drawback to the tank's effectiveness, meaning it only had an off-road range of up to 110 kilometres.

A destroyed Tiger II 'King Tiger': production costs also hamstrung the Tiger's successor

Killing machine

Precision engineering made this German heavy tank a lethal adversary in its day



Engine
The Tiger I was fitted with a re-engineered 700-horsepower engine, fed by four fuel tanks capable of carrying 534 litres.

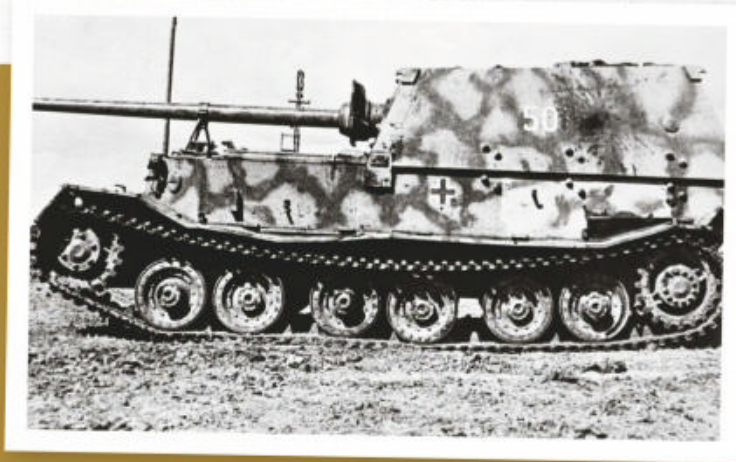
Tracks
The Tiger's tracks were wider than average to provide extra traction and were fitted with a suspension system to withstand rough terrain.

Wheels
Early models featured 48 steel wheels with rubber tyres, 24 each side, while later variants were fitted with 32 all-steel wheels.

Other big cats

Although the Tiger I was the most numerous and notorious of Nazi Germany's heavy tanks, several other versions were also developed to tackle specific combat scenarios. The Panzerjäger Tiger, or 'Elefant', was a tank destroyer based on the chassis of a Tiger but designed to hunt down enemy vehicles. The Elefant featured a fixed turret, meaning that it could not rotate to adjust its aim, and its 88mm gun therefore stretched out across the front of the chassis, resembling an elephant's trunk.

Another short-lived Tiger variant was the Sturmtiger, an assault gun that was developed with one job in mind – to demolish anything and everything that stood in its way. Armed with a massive 380mm cannon, the Sturmtiger fired rocket-propelled shells that could lay waste to massed enemy positions, or even obliterate buildings. Only 19 Sturmtigers were ever developed, making them another curious but small footnote in the history of the Tiger tank.



The Elefant featured a fixed 88mm gun on a Tiger chassis and was deployed as a tank destroyer

Evolution of German armour

PANZER I
1934
Small, nimble and lightly armed with two machine-guns, these tanks were manned by just two crew members.

PANZER IV
1937
Fitted with a 75mm turret cannon, this was the most numerous German tank during WWII, with over 8,000 produced.

TIGER I
1942
With a huge 88mm gun, the Tiger I favoured firepower over the greater manoeuvrability of the Panther.

PANZER V PANTHER
1943
Developed to tip the balance on the Eastern Front, its sloped armour plating increased its effectiveness against horizontal ballistics.

TIGER II
1944
The King Tiger combined the effective sloped armour of the Panther with an improved 88mm cannon.

PANZER VIII 'TIGER MAUS'
1944–5
The 'super heavy' Tiger II successor would have carried a 128mm cannon, with 250mm sloped armour. The project was never completed.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


JODIE TYLEY


TOM LEAN


LAURA MEARS


JAMES HORTON


JO STASS

Do mice prefer cheese?

Daniel Hobbs

Studies show that, while mice will eat cheese, particularly if they are hungry, given the choice they seem to prefer other foods, especially sweeter foods like grains and fruit. **TL**

Want answers?

Send your questions to:

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@howitworks@futurenet.com

Why does crying make my nose run?

Kate Upson

When you cry, tears not only fall down your face but also travel from the inner corner of your eye into your nose via the nasolacrimal ducts. This is actually happening all the time, but when you cry there are more tears to mix with the mucus in your nose, producing runny snot. **JS**

What would happen if I put rocket fuel in my car?

Philippa Wright

■ Sadly, nothing too exciting. Rocket fuel contains kerosene, which is a bit like diesel. So if your car runs on diesel fuel, it might still start. If your car runs on petrol, rocket fuel could cause the engine to misfire or cut out altogether. **LM**

How does chemotherapy work?

Ben Charleston

■ Cancer happens when some of the body's cells divide uncontrollably to create a mass of new cells called a tumour. Chemotherapy uses drugs to kill cells that are in the process of dividing, meaning they can shrink the tumour or even cure them sometimes. Chemotherapy affects some healthy cells too, which causes side effects, but as cancer cells divide more frequently they are more likely to be affected, making chemotherapy effective at targeting many cancers. **TL**

Chemotherapy uses a variety of drugs to kill cancer cells

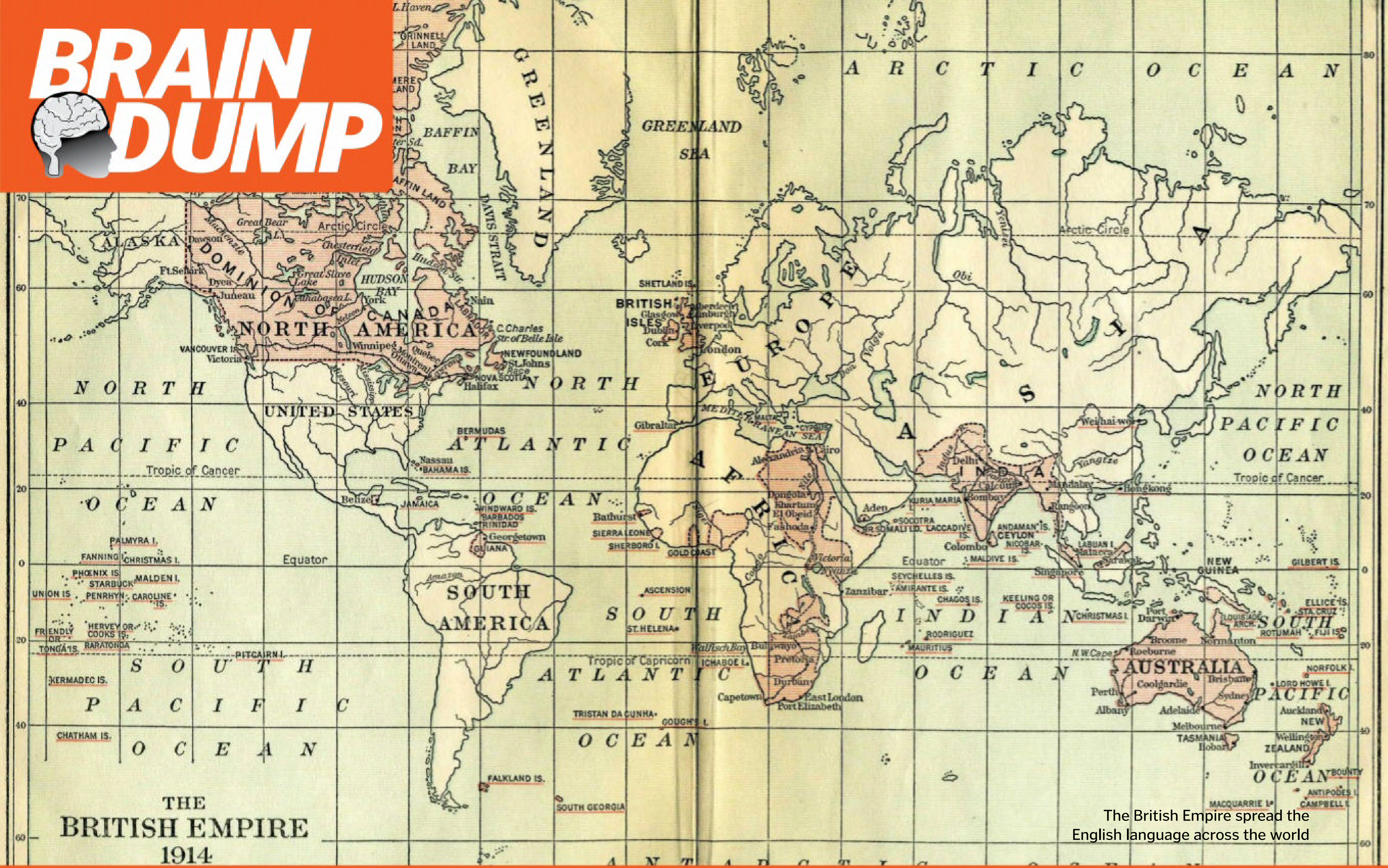
How long does it take to get to the Moon?

Matt Hansel

■ Despite looming large in the night sky, the Moon is further away than you might think. It takes about three days to travel to the Moon, covering an average distance of 384,400 kilometres – that's the equivalent of around 30 Earths! **JT**

© Getty: NASA

BRAIN DUMP



The British Empire spread the English language across the world

Why is English an international language?

Francis Towers

■ The most spoken language in the world is Mandarin Chinese, with 918 million native speakers. The next most spoken language is Spanish (460 million) and then English, with 340 million native speakers, comes in third. However, English is the official language of more than 60 countries, and this is all down to the British Empire. At its height, the empire covered around a quarter of the Earth, and the English language remains important in former colonies to this day. **LM**

Why do mobile phones today have such a bad battery life?

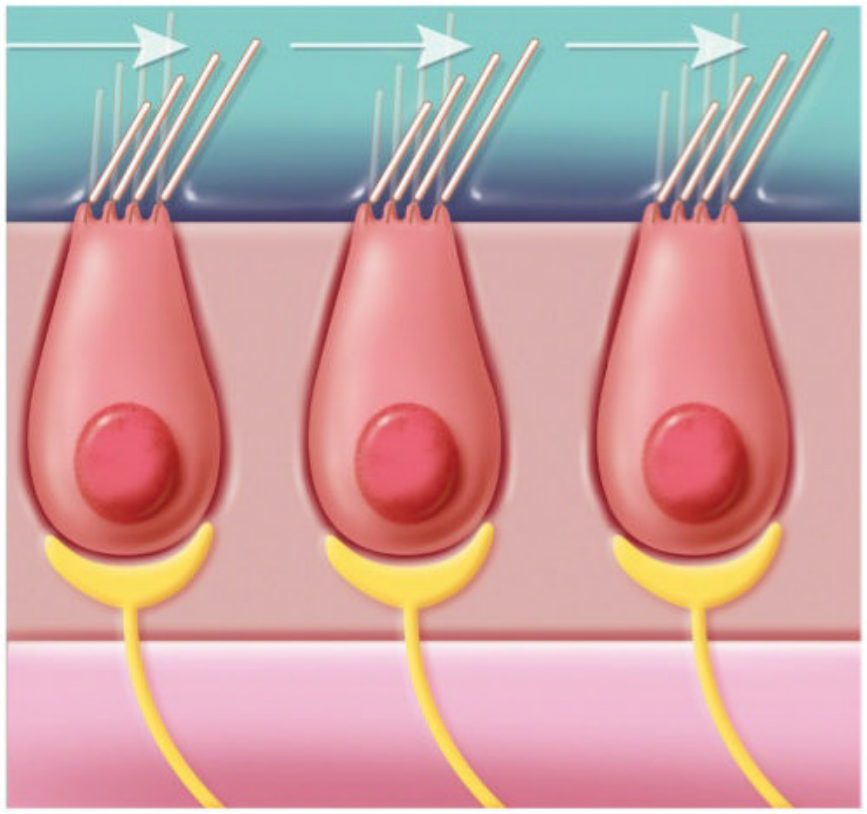
Ruben Tate

■ 20 years ago your mobile couldn't do much apart from make phone calls, send texts and run simple programs, but it could last for days without the battery dying. Modern smartphones are lucky to get through one day without needing to be charged because they do so much more than older phones. Apps, GPS, always-on internet, cameras, media players, messenger software, big display screens and all the other features we've come to expect mean that smartphones need much more power to run than older phones did. However, battery development hasn't kept up with these changes, so modern smartphones often have worse battery life. **TL**

Why do you never see baby pigeons?

Kai Perry-Johnson

■ Pigeons descended from wild rock doves, and they still tend to nest in high-up places to hide from any would-be predators. Fledgling pigeons also spend a long time in the nest and only leave once they're fully grown. **JT**



Sound waves cause the hair cells in the inner ear to move, sending electrical signals to the auditory nerve, which carries the message to the brain

Why do you sometimes get a ringing sound in your ear?

Sebastian Ordoñez

Hearing noises that aren't from an outside source is called tinnitus. It's very common, affecting all age groups, and it can come and go. The exact cause is still not known, but tinnitus has been linked to hearing loss through ageing and to being exposed to loud noises at a live concert, for example. Standing too close to the speakers can damage the hair cells inside our ears. It's their job to convert sound waves into electrical signals that travel to the brain, but when they are damaged they keep sending signals and create the illusion of sound. **JT**

Nail polish remover contains a solvent that dissolves the polish

How does nail polish remover work?

Hannah Hersey

The main ingredient of nail polish removers is acetone – a clear, strong-smelling and highly flammable liquid. Acetone is a very good solvent, which means it can dissolve other substances. On the other hand, nail polish is a hardened polymer. Polymers are a type of substance made up of many molecules bonded together. The acetone molecules get in between the polymer molecules, causing them to break up so that the polish is dissolved. **JT**

Beef and dairy cattle contribute nearly half of our food-based greenhouse gas emissions

Why would the planet be better off if we were all vegetarian?

Alicia Odense

An estimated 14.5 per cent of human greenhouse gas emissions come from livestock. Of that, around 40 per cent comes from cow farts, 25 per cent from rotting manure and 13 per cent from growing animal feed. Animals live on around 70 per cent of our farmland and eat nearly half of the grain we grow. If we all went vegetarian, we could turn much of that land back to nature. But a sustainable food chain doesn't necessarily mean giving up on animal products entirely. A newly designed 'planetary health diet' could support a human population of 10 billion, while still allowing us to eat a little meat, fish and dairy. **LM**

Why do some people hate the taste of coriander?

Monica Fernandes

There may be cultural reasons why people don't like the taste of coriander, but it's likely there's also a genetic factor. Scientists think that many people who find coriander unpleasantly bitter have a gene variant that makes it taste differently for them, compared to those who find coriander pleasantly zesty. **TL**

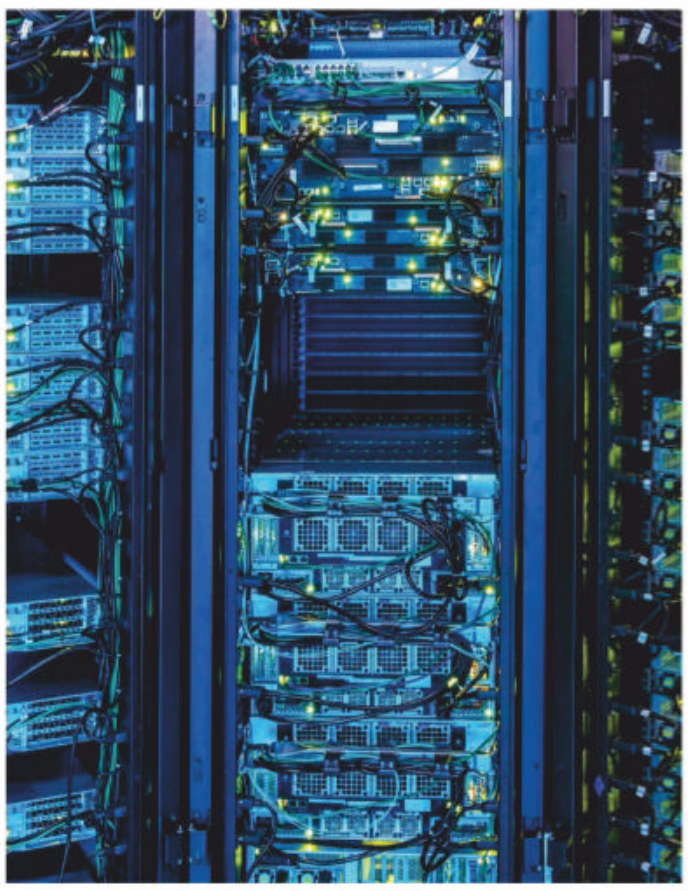
© Getty; Alamy

BRAIN DUMP

One day, will we be using rockets to travel from one side of the planet to the other?

Lucinda Delaney

■ Elon Musk's rocket company, SpaceX, has proposed using its new rocket (which is currently in development) to propel people around the globe. If successful, we'll be able to travel to any major city in under an hour. **JH**



How big is the biggest data storage in the world?

Omar Sattar

■ China's Inner Mongolia Information Park is the world's largest data centre, spanning 99.4 million square metres. It contains a cloud computing data centre, call centres, warehouse, offices and living quarters for staff. It uses as much electricity as a small town. **JS**

What determines if a cloud is white or grey?

Alan Grant

■ Clouds are made of large water droplets that scatter all of the wavelengths of light from the sun equally. This causes all of the colours of light to combine and appear to us as white. As the scattered light is usually directed towards the top or sides of the cloud, the bottom receives less light, making it appear darker. In rain clouds, the water droplets are bigger and scatter more light, meaning even less light reaches the bottom of the cloud. This gives the bottom of the clouds a gloomy grey appearance, but at the top they are still bright white. **JS**

Rain clouds are grey because they contain larger water droplets

Do donated organs ever get re-donated?

Lucy Welles

■ In some instances, yes, although this usually only happens if the first recipient of an organ dies shortly after the implant. It is a rare procedure because living in two bodies, especially those that are severely ill, can cause serious harm to an organ. Add to this the scar tissue that accumulates after surgery, and the result is an organ that's usually too damaged to aid a third person. **JH**

What would happen if the Earth spun faster?

Atticus Barnaby

■ A little increase wouldn't affect much, but we'd have to change our clocks as our days would become shorter. At extreme rotation rates, however, the centrifugal force would be so great that it could overcome gravity and fling us off the planet! Fortunately, the Earth would need to rotate about 17 times faster for this to happen to people on the equator. **JH**

What's the most valuable treasure found by a metal detectorist?

Robert Darwin

Most of us amateur metal detectorists are lucky to find anything other than bottle caps as we patiently survey the beachfront, but a fortunate few have used these tools to uncover amazing troves of treasure. In California, the 'Mojave Nugget' was unearthed and valued at roughly £150,000. In England, Iron Age jewellery, Bronze Age crockery, Roman relics and Anglo-Saxon metalwork have all been discovered and sold for huge sums, the most valuable of which was worth £3.3 million! But the champion metal detector find on land goes to two men who found 50,000 Roman coins in a field in Jersey. The huge stash has an estimated value of around £14 million! **JH**

The Mojave Nugget is the largest golden nugget ever to be found in California

Want answers?

Send your questions to:

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Why do babies constantly cry?

Billy Brands

Crying babies might be hungry or tired, they might have a dirty nappy or trapped wind, or they might just need comforting. Unfortunately, it's not always easy to tell what they're asking for! **LM**

Gregor Mendel is considered the father of modern genetics

Who discovered genes?

Sean Horson-Jones

Austrian monk Gregor Mendel was the first to discover the basic principles of inheriting traits. Between 1856 and 1863 he crossbred thousands of pea plants, documenting their height, shape and colour, and noted that dominant and recessive traits were passed on randomly from parents to offspring. He published his findings in 1866, but it wasn't until other scientists discovered them decades later, long after his death, that he was recognised as providing the foundation of genetics. **JS**

BOOK REVIEWS

The latest releases for curious minds

Lost In A Good Game: Why We Play Video Games And What They Can Do For Us

The science of gaming

■ Author: **Pete Etchells** ■ Publisher: **Icon Books** ■ Price: **£14.99 / $17.95** ■ Release: **Out now (UK) / 11 June (US)**

Ask ten people why they play video games and it's likely you'll get ten very different answers. It might be that one plays the odd game of *Candy Crush* to pass the time during their commute, while another might sink hours into the latest *Call Of Duty* every weekend. Gaming has become a phenomenon, and it's changing the world.

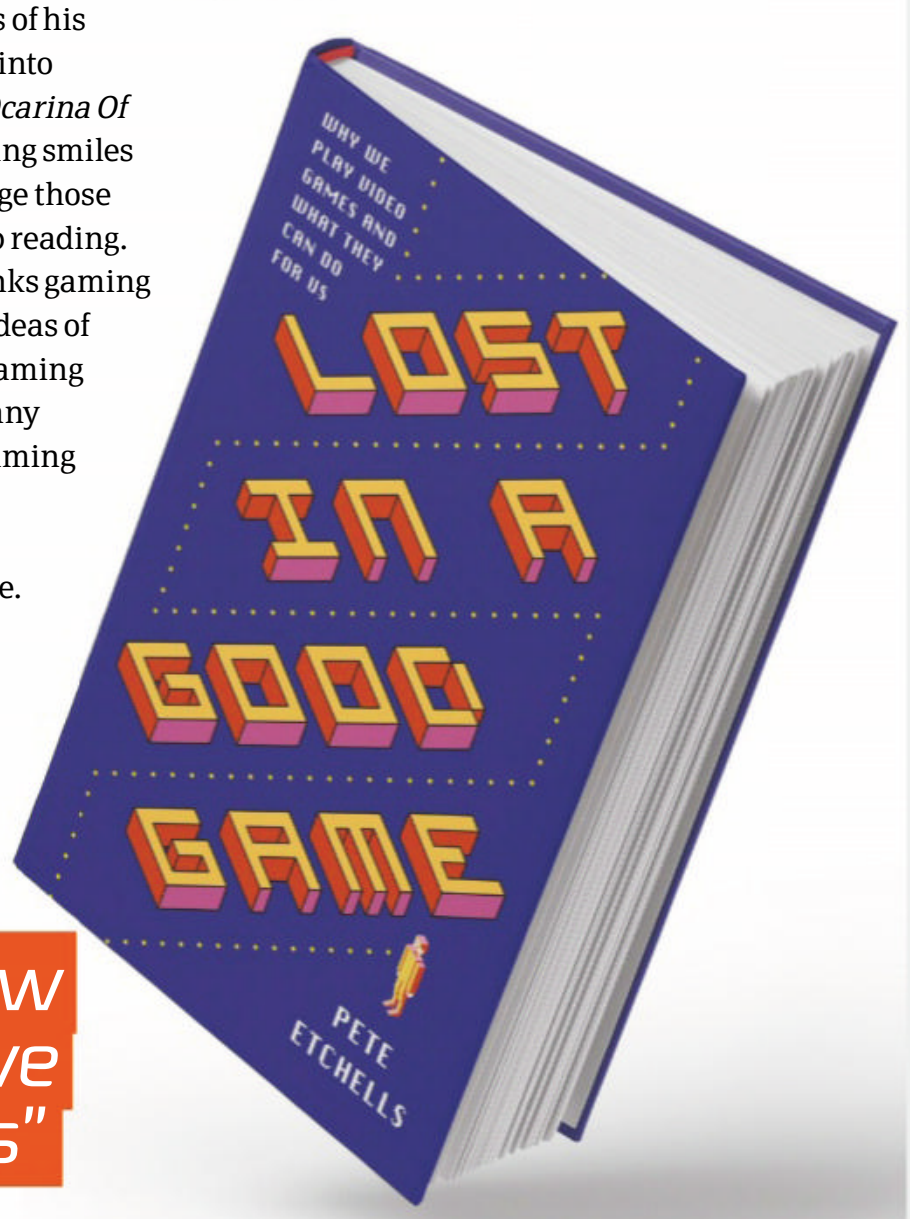
Phil Etchells explores this idea in *Lost In A Good Game*. It begins with a personal account of his experiences with gaming – something that continues throughout the book and helps to keep everything grounded. While the main focus is on psychology and social study, Etchells's own stories of his favourite games, as well as personal insights into his life, are what keep us turning the pages. Each chapter brings different tales to the fore, from the loss of his father to his first experience stepping into Hyrule Field in *The Legend of Zelda: Ocarina Of Time*. These snippets will elicit knowing smiles from gamers but will equally encourage those who rarely pick up a controller to keep reading.

Perhaps unsurprisingly, Etchells links gaming to all kinds of topics. He explores the ideas of loss, escapism and agency, and how gaming can arguably reflect these more than any other media. He discusses whether gaming has any link to violence. They're old questions, but here they're answered with scientific study and real expertise. It's refreshing.

He also explains how gaming can have more positive effects on the world. We learn about a mobile game that helps scientists better understand Alzheimers, and the phenomenon that is esports – a term to describe professional gamers that play against each other in huge tournaments watched by millions of people worldwide. It's effectively a world cup of video games, bringing excitement and joy to gamers who never enjoyed football.

It's unsurprising, giving Etchells's clear love of gaming, that *Lost In A Good Game* mainly has good things to say about the pastime. But he backs up his points with scientific study and tells stories with such skill that it's easy to believe him. Are games ruining our society? We may never be able to prove it either way, but Etchells does a great job of reassuring us that, as long as we're having fun, there isn't any need to worry. Game on.

★★★★☆



"He explains how gaming can have positive effects"

Sunfall

The end is nigh

■ Author: **Jim Al-Khalili**
■ Publisher: **Bantam Press**
■ Price: **£16.99 (approx $22)**
■ Release: **Out now**

Physicist and TV personality Jim Al-Khalili turns his hand to fiction with surprising results, his debut novel providing a livewire and at times utterly terrifying look at an end-of-world scenario that you probably never even thought to consider.

In the not-too-distant future, the world's population having clubbed together to stave off the more disastrous consequences of climate change, humanity has settled into a state of complacency. But when a series of extreme weather phenomena devastate parts of the planet, an even more cataclysmic possibility presents itself: that of the Earth's magnetic field failing. Faced with the prospect of Earth becoming uninhabitable, scientists race against time to find a solution.

Armed with the background knowledge to make his pronouncements plausible, Al-Khalili sketches out a world and characters that are believable (even if their willingness to work together seems somewhat optimistic in today's political climate) alongside a plot full of sudden turns. For a debut author, his ability to craft a book that seems determined to remain lodged in your hands frankly makes us slightly envious of his multiple talents.

All in all, it's a promising start for Al-Khalili and denotes a new career path that we hope he continues to follow.

★★★★☆

Cosmic Impact: Understanding The Threat To Earth From Asteroids And Comets

Collision imminent

- Author: **Andrew May**
- Publisher: **Icon Books**
- Price: **£8.99 / $14.95**
- Release: **Out now (UK) / 14 May (US)**

We've all seen the alleged destructive potential of giant objects being hurled at us from space, thanks to big-budget Hollywood blockbusters like *Armageddon* and *Deep Impact*. But how likely is the prospect of such an event occurring, and what would be the consequences? All this and more is answered within these pages.

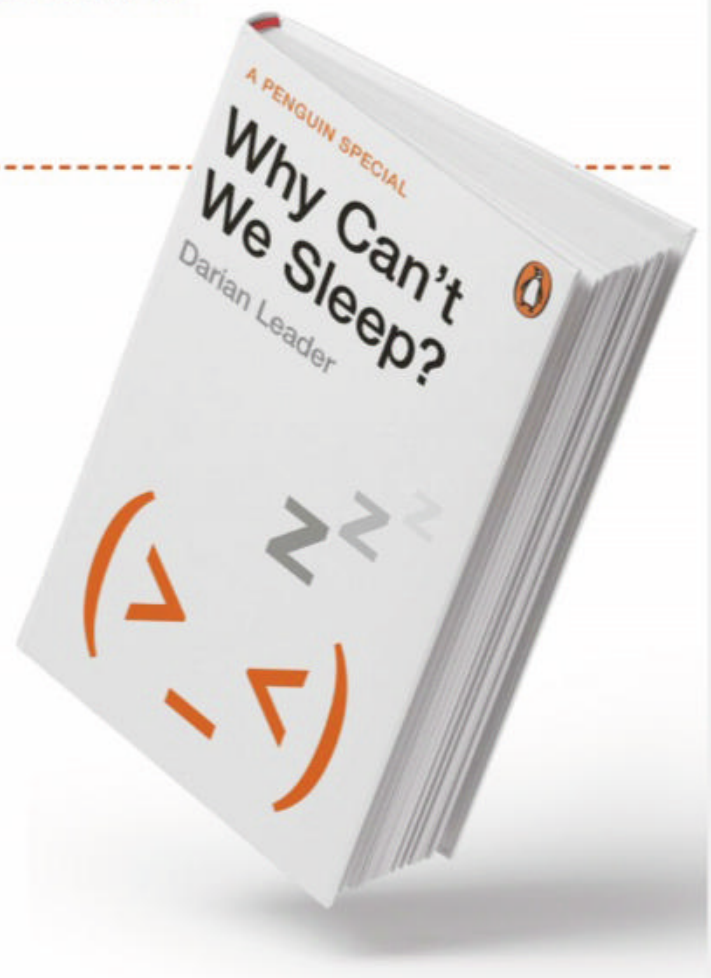
Unsurprisingly, it turns out that the movies were playing with the science for dramatic effect. The chances of a real-life collision with something on the scale of those seen on the screen is extremely unlikely, and, if at all, won't occur for a very long time. Even so, it is still possible, and the facts that Andrew May reveals make for an insightful, if at times chilling, read.

Books like this aren't always the most accessible, but May clearly recognises that its audience is more than just academics. By drawing frequently on the works of authors like Arthur C. Clarke and the aforementioned movies, he grounds this in a manner that is relatable to both casual reader and academic alike.

It may arguably be the science equivalent of a destruction derby, but any book that encourages people beyond its usual audience to get acquainted with science is a good thing.

★★★★★

Why Can't We Sleep?



The story of insomnia

- Author: **Darian Leader**
- Publisher: **Penguin**
- Price: **£6.99 (approx $9)**
- Release: **Out now**

Ever been troubled by a lack of sleep, or been unable to answer a younger one's question regarding the same thing? It could well be that *Why Can't We Sleep* has the answers you've been looking for, even if they aren't necessarily the ones you were expecting.

That author Darian Leader manages the feat of simultaneously drawing on multiple academic case studies while at the same time largely remaining jargon free (although inevitably some humdingers slip through) is admirable. Even if this isn't a malady you suffer from, there's still plenty of food for thought contained within the pages here.

At the same time, its application as a self-help guide can be viewed as questionable, and some of its statements regarding the causes of lack of sleep are at times tantamount to stating the obvious. Regardless, there's a lot to take in, so we can't dismiss it entirely.

★★★☆☆

Paper World: Planet Earth

What lies beneath?

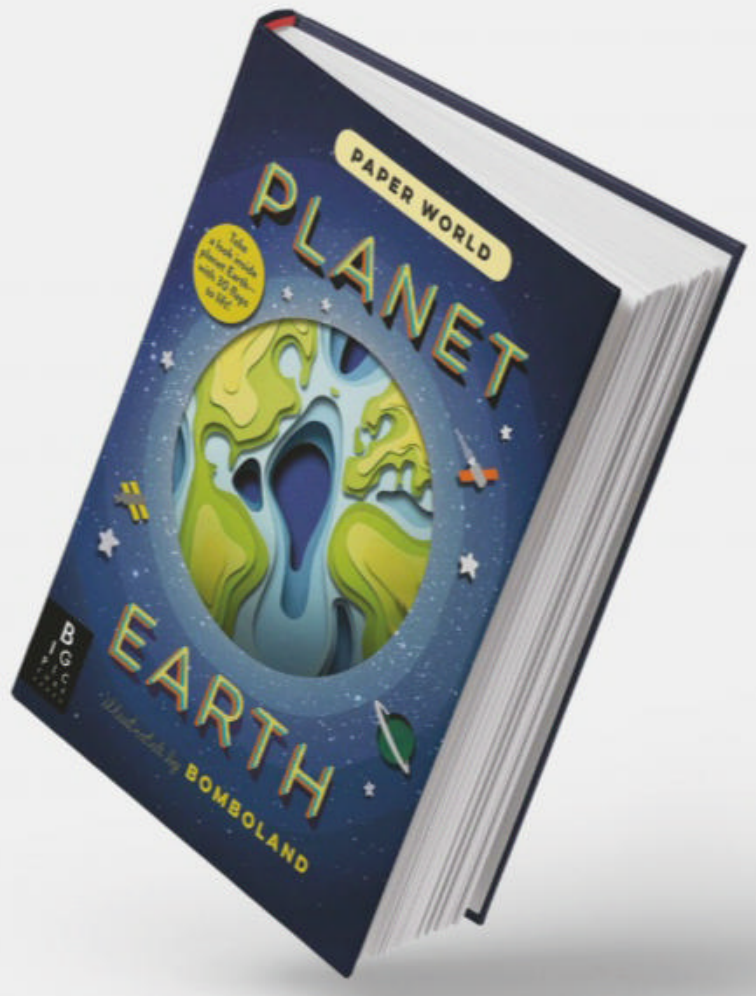
- Author: **Ruth Symons, Bomboland**
- Publisher: **Templar Publishing**
- Price: **£15.99 / $24.99**
- Release: **Out now (UK) / 17 September (US)**

Lift-the-flap books (for lack of a better term) are highly undervalued and should be brought back. There, we said it. Thankfully, it looks like two-piece Italian illustration studio Bomboland has read our minds, duly unveiling a layered (literally) guide to the planet that we call home.

Containing guides to rivers, caves, volcanoes, mountains and much more, this serves as an insightful guide to Earth for younger readers, cutting open the landscape one notable feature at a time and laying its secrets bare for all to see. Side by side with the illustrations are bitesized annotations, perfectly pitched towards the target audience's attention spans.

Realistically this is probably for those aged nine and below, and it's something they'll undoubtedly get through quickly, but also something they'll likely want to return to. Hopefully this is a sign of more to come in a similar vein from the folks at Bomboland.

★★★★☆



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b) **Red Bull**

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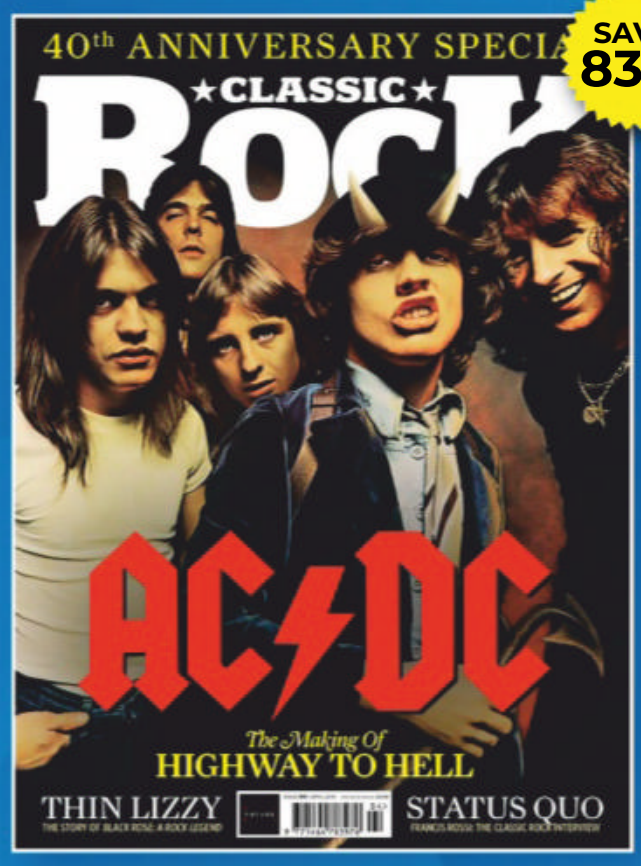

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BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

A	R	P	O	X	X	V	L	I	R	Q	P	P	X	S
N	U	S	Y	J	U	P	I	T	E	R	G	Z	M	O
I	G	G	H	A	G	N	X	C	K	K	W	A	H	N
N	U	P	M	X	D	T	I	G	E	R	I	I	D	G
C	I	C	U	E	S	S	Z	E	J	K	J	D	X	B
I	B	O	B	X	N	B	N	M	L	A	X	H	I	I
N	X	N	E	W	Q	T	X	F	A	L	F	E	C	R
E	L	G	J	S	A	D	E	C	U	A	E	N	N	D
R	E	R	T	E	T	Y	G	D	T	H	H	R	I	M
A	N	E	S	M	W	X	T	X	R	A	Y	Y	V	J
T	S	S	L	A	B	R	E	A	I	R	P	V	A	V
O	I	S	C	H	Z	G	F	Z	V	I	R	I	D	M
R	N	X	V	T	X	C	W	R	E	R	I	I	T	R
X	G	M	A	M	M	O	T	H	X	L	S	I	L	S
R	E	C	Y	C	L	A	B	L	E	X	M	B	F	X

FIND THE FOLLOWING WORDS...

MAMMOTH
DAVINCI
PRISM
AUGMENTED
LENSING
SONGBIRD
JUPITER
KALAHARI
INCINERATOR
THAMES
VIRTUAL
RECYCLABLE
HAWK
HENRYVIII
LABREA
CONGRESS
TIGERII

Quickfire questions

Q1 Which of these are bones in the foot?
- Phalanges
- Metacarpals
- Femurs
- Vertebrae

Q2 What is the world's biggest desert?
- Sahara
- Kalahari
- Antarctic
- Gobi

Q3 How fast can a Hawk T1 travel?
- 280 kilometres per hour
- 170 kilometres per hour
- 1,000 kilometres per hour
- 1,845 kilometres per hour

Q4 What gas forms most of Earth's atmosphere?
- Oxygen
- Carbon dioxide
- Nitrogen
- Hydrogen

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

1	5		4	9	2		8	7
9	7	8					4	
2	4		8	5			3	1
6	1	9		8		4	7	2
5	8	4		2		1	9	
		7		1	4			
	9	1	5	6	3	7	2	8
7		5	2				1	
8	3				9	5	6	

DIFFICULT

3		4				9	7	
			8	4				
		2				4	8	3
					1			5
7		9						
					2			
	5					3		1
			7				5	
	9		1	5	8	7		4

What is it?

Hint: This marine creature is the flower of the sea.

A .....

© Getty

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 5,504.85° Celsius

Q2 Black mamba

Q3 1829

Q4 Methane

What was it?

Pepper

Get in touch
Send your ideas to...
How It Works magazine
@HowItWorksmag
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Spin a basketball

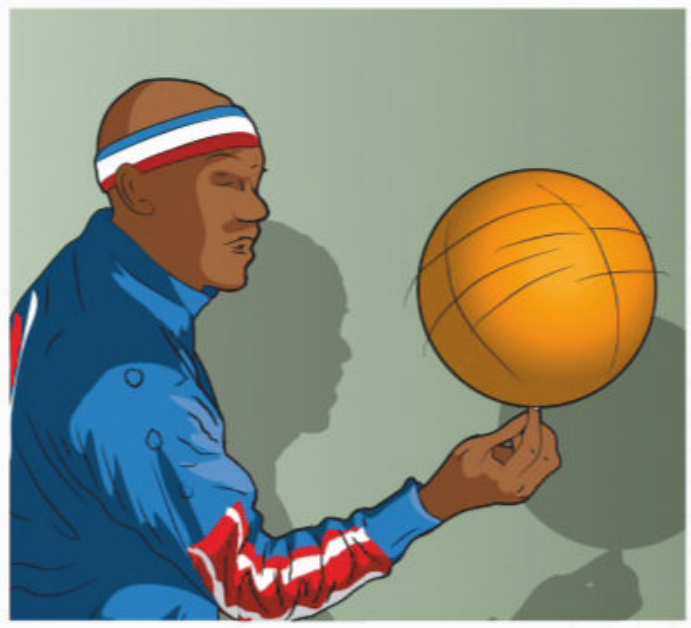
Learn how to balance a spinning basketball on your finger... and keep it spinning

1 Get the spin right

Grip the ball with two hands, one in front and one behind. Spin the ball in the direction you feel is the most comfortable, but remember – you need to make sure the point of axis is at the bottom of the ball.

2 Perfect the catch

Throw the ball into the air as you spin, and keep your eye on that exact point on the bottom of the ball. Hold up your finger, and as the ball comes down catch it on your finger, slowing it down as it lands.



3 A strong finger

If you use the pad of your finger, it will create more friction with the ball and slow down the spin. Balance it on your fingernail to reduce this friction and keep it spinning for longer, and support you finger with the others.

4 maintain the speed

If the ball starts to slow down, use your other hand to swipe it to keep the speed up. Thanks to the centripetal force being exerted on the ball, swiping it with speed in the right place will not knock it off.

5 Keep balance

If the initial spin of your ball was good and you can keep the speed of the spin going, you shouldn't have too much trouble maintaining balance. This is because the angular momentum of the ball is stronger than the pull of gravity.

6 Practise

We've made it sound easy, but this skill is a really tough one to learn, and it will take at least a few hours to get your first successful spin. Keep practising each element, and eventually you can start trying other tricks.

NEXT ISSUE
Create a ferrofluid

SUMMARY...

As you spin the ball, it creates angular momentum that moves the ball in a circle, and centripetal force that acts towards the centre of the spin. When the ball is balanced on its central point, these forces are more powerful than the gravity that pulls the ball downwards, causing it to remain upright. As it slows, due to friction and air resistance, these forces weaken until eventually gravity causes the ball to topple.

Had a go? Let us know! If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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The old faithful horse-and-cart milkman still delivers many people's morning milk across the globe

Letter of the Month

Four-legged milkman

Hi **HIW**,

Once again my son has renewed my subscription to the magazine for my Christmas present. I have every issue from No. 1 and always look forward to receiving the next one. I have today received issue 122 and was fascinated by the article about "Horse Power". Back in the 1950s I worked for the Co-op Dairies in Hall Green, Birmingham and at that time milk was delivered by horse and cart. My horse was named Daphne and she would greet me, with a neigh, every morning when I entered her stable at 6.00.am, to put her harness on for the daily deliveries. In the winter I had to put segs in her hooves to stop her sliding on the ice. It was a shame when she was retired to make way for the electric wagons. I wonder if milk is delivered in this way anywhere in the world today? I also enjoy the "Brain Gym". I do the word search and "Spot the difference" and my wife enjoys the "sudoku". My wife and I run a group called Crafts & Coffee and I always tell the members about the "Fast Facts". It all helps to keep the old grey matter going.

Malcolm Turner, aged 81

Thank you for writing to us Malcolm, what a great time the two of you must have had.

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
SCHRÖDINGER'S CAT AND 49 OTHER EXPERIMENTS THAT REVOLUTIONISED PHYSICS

Though the horse-drawn milk cart and indeed its electrical replacement are no longer the norm in Britain, in certain parts of the world delivering milk by horse is still fairly common. For example, in Srinagar, the largest city and the summer capital of the Indian state of Jammu and Kashmir, horse-drawn carts can be seen delivering milk to local people, even in the freezing cold.

Also, a few European countries such as Romania and Moldova have towns where their morning milk is still brought on horseback.

© Getty

Moon landing mystery

Hi **HIW**,

I've been meaning to ask this for a while now, but in late 2018 I watched *First Man* (Moon landing of 1969) at the cinema when it first came out. I came back from the film interested about the topic of the Moon landing and how they actually got to the Moon. Because of this I looked it up the next day for more detail on the landing and this was when I stumbled across some (conspiracy) theories about how the Moon landing did not happen and was faked. What I would like to know is: are these theories actually true or false?

Harry Durrant

That's a fair question Harry: as you said, there are a lot of theories claiming to disprove humans ever landed on the Moon. However, there are a couple of pieces of evidence that categorically prove Neil Armstrong took those first steps on the Moon. Firstly, the mission brought home pieces of the Moon's surface, analysed by 135 countries that concluded its lunar origins. Secondly, the landing team placed reflective panels on the Moon's surface, and upon their return lasers were shot at the panels and the beams came back. This can be repeated today. Also, it's a pretty big secret to keep if the whole thing was a hoax. For more answers on this topic, check out our conspiracy debunked article at howitworksdaily.com.

The Moon landing certainly did happen in 1969, though it's a bigger wonder that the Moon landing hoax conspiracy theory endures to this day

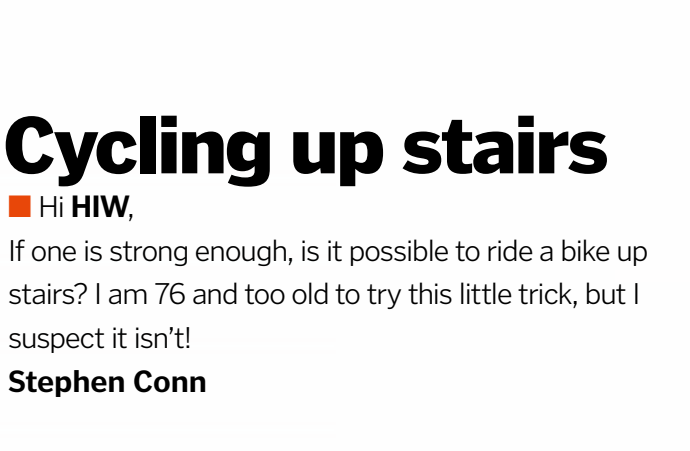
Cycling up stairs

Hi **HIW**,

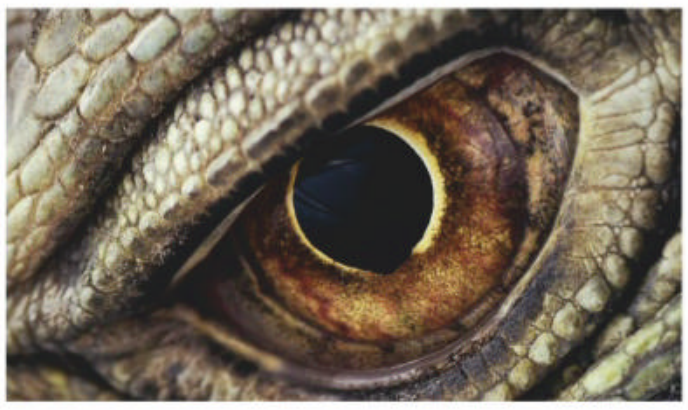
If one is strong enough, is it possible to ride a bike up stairs? I am 76 and too old to try this little trick, but I suspect it isn't!

Stephen Conn

Physically it is possible to bike up stairs. With just the right momentum and pedal force, a rider would be able to power up each step, though typically only up a short series of steps. It would be incredibly hard to scale an entire staircase as only superhuman momentum would carry the rider to the top. There are also an array of things that can go wrong in attempting it, so I'd stick to flat surfaces if I were you.



Polish cyclist Krystian Herba set the Guinness World Record for stair climbing, climbing 3,461 stairs in 2016



Real-life dragons

Hi **HIW**,

I am an avid reader of your magazine and as such I am asking you a question: what if dragons (i.e. Smaug) were real? What would their habitat be and what would their internal organs be like?

Barnaby Sharratt

We like your question Barnaby. Considering dragons are essentially fire-breathing lizards, you could assume that their habitat and internal structure would be similar to real-life lizard examples, such as the Komodo dragon in Indonesia. Their flame-throwing abilities could come from an organ near the throat, a gland that produces an organic napalm-type gel that reacts with the air, projected down its throat (which is coated with protective mucus) and exits the dragon's mouth as a lava-hot flame.

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"Year 8s deep into @HowItWorksmag to find evidence of how energy is going to be used in the future and what products might be out there. Finding their first piece of #OK. #NextStepAlevelGeography"

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66

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